The Report Committee for Michael Ty Measom

Certifies that this is the approved version of the following Report:

Vaccine Misinformation vs Debiasing Efforts:

Understanding the Psychological Tools Applied to Vaccine Misinformation and Applying Them

to Vaccine Debiasing Efforts

APPROVED BY

SUPERVISING COMMITTEE:

Veronica Yan, Supervisor

LuAnn Wilkerson

Vaccine Misinformation vs Debiasing Efforts:

Understanding the Psychological Tools Applied to Vaccine Misinformation and

Applying Them to Vaccine Debiasing Efforts

by

Michael Ty Measom

Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Education

The University of Texas at Austin

May, 2021

Abstract

Vaccine Misinformation vs Debiasing Efforts:

Understanding the Psychological Tools Applied to Vaccine Misinformation and

Applying Them to Vaccine Debiasing Efforts

Michael Ty Measom, M.Ed.

The University of Texas at Austin, 2021

Supervisor: Veronica Yan

Efforts by anti-vaccination movements date back to the conception of life-saving vaccines and have found considerable success in the US and Europe despite the overwhelming scientific data proving the safety and efficacy of vaccines. An analysis of vaccine misinformation reveals a plethora of psychological strategies employed by misinformers to help the false information become durable components in learners' knowledge schemas about vaccines. While Conceptual Change researchers have proposed various models of conceptual change, including Posner et al.'s Conceptual Change Model, to aid educators in correcting misconceptions, these models have fallen short in correcting vaccine misinformation. This is partially due to several shortcomings in the models which have recently been addressed in Kendeou et al.'s Knowledge Revision Components Framework, which stresses the importance of strengthening the activation potential of correct information once the education intervention has occurred. In this report we

suggest how the same strategies employed by anti-vaccination movements can be employed by educators through refutation texts to ensure correct information about vaccines can outcompete vaccine misinformation for activation.

Table of Contents

Introduction

In the late 1990's, a group of parents sued vaccine manufacturers because of their belief that vaccines had harmed their children. Because no substantial evidence existed to support these claims, the litigating lawyers sought out evidence through nefarious avenues (Godlee, 2011). Arrangements were made to pay researchers to fabricate data that suggested the MMR vaccine is associated with Autism Spectrum Disorder. In 1998, Dr. Andrew Wakefield and his colleagues accepted under-the-table payments and published false findings in *The Lancet*, a highly distributed and influential medical journal (Deer, 2011). Thanks to investigative journalism, this scandal was fully uncovered by 2010. The journal article was retracted, and Dr. Wakefield was stripped of his medical and research privileges. Nevertheless, the damage was already done. In the years following the original publication, MMR vaccination rates fell to below 80% and many UK and US citizens still cite the false link between the MMR vaccine and ASD when questioned about vaccine hesitancy (Alazraki, 2011). Sadly, the actions of the litigation team and research team have left hundreds of thousands of children vulnerable to deadly, highly preventable diseases.

The aims of this paper are to examine the state of vaccine hesitancy in today's socio-cultural context and the educational theories, strategies, and tools that seek to address the effects of widespread false beliefs about vaccines. Specific attention will be paid to refutation texts, a style of teaching scientific information by first refuting common misconceptions, as they are one educational tool that has an extensive literature base and entrenchment in educational psychology theory (Maria & MacGinitie, 1987). Furthermore, refutation texts hold potential as an intervention that can be easily shared by frontline healthcare workers, public figures, and social media influencers with very little training in education. However, our immediate attention is

directed to the false information that refutation texts are attempting to correct. Understanding

why anti-vaccination beliefs are appealing and enduring will provide insights to the challenge

educators face to dispel such myths and to what enhancements can be added to refutation texts to

make them a viable tool against vaccine misinformation.

A Brief History of Anti-Vaccination

Anti-vaccination sentiments date as far back as the early vaccination movements for smallpox in the late 1700s (Millard, 1948). Despite the actual safety concerns at that time, movements against public health vaccination campaigns cited similar themes to today's rhetoric including civil liberties, religious beliefs, and efficacy (Millard, 1948). It was not until decades later that sterile techniques reached a level that scientists today would consider safe for public use. Not uncommonly, patients would contract tetanus, toxoplasmosis, or syphilis from early smallpox vaccines (Geddes, 2006). Despite these health risks and the formidable opposition to widespread vaccination, early vaccines saved hundreds of thousands of people from unnecessary illness and potentially lethal infections (Geddes, 2006). The intimate experience of losing so many family members and neighbors to smallpox, and the overwhelming effectiveness of the vaccine, is likely what ultimately led to successful vaccination campaigns throughout Europe and the United States. Throughout the 1800s, Britain continued to develop vaccines and push for widespread vaccination. The stronger they pushed to mandate vaccines; the more anti-vaccination sentiments grew (Millard, 1948).

These organized anti-vaccination movements eventually migrated to the United States where they found financial backing and public support (Wolfe, 2002). Vaccine development continued to improve as scientists developed sterile procedure, better testing agents, refined study designs, and antibiotics (Wolfe, 2002). The threat of deadly diseases like mumps, measles, and polio helped mass vaccination efforts despite the growing influence and attacks of anti-vaccination groups. Opposition to vaccines continued to cast doubt on the efficacy and safety despite the hundreds of thousands of lives saved. Religious themes of opposition remained prevalent in anti-vaccination dialogues as many Christian denominations aligned with naturopathic philosophies

or abstained from the rubella vaccine because of its derivation from abortion tissue (Plotkin, 1985). Even mainstream denominations took vaccine hesitant stances when vaccines were developed against sexually transmitted diseases (Smith, 2015). The rise of alternative medicine philosophies, added a new group of special interests to fuel anti-vaccination movements (Ernst, 2001). Naturopathy, chiropractic medicine, and other complementary healthcare fields theorize that bodily illness can be effectively treated with natural remedies, certain foods, or bone adjustments and minimize the need for modern pharmaceuticals. Unfortunately, many of these types of providers include vaccines as western medicine that should be avoided (Caulfield et al., 2017). It would seem that as the scientific community exerted more and more effort to improve safety, sterility, and scientific evidence to ease people's concerns, the opposition focused more efforts on emotional, cultural, and identity-based persuasion strategies. Paradoxically, these efforts by the scientific community have made vaccine campaigns more, rather than less, difficult because the effectiveness of vaccines weakens the general public's motivation to vaccinate (Lewandosky et al., 2012). The once scary diseases like measles, mumps, polio, and smallpox are no longer an intimate threat to health as they were in the 1800s and 1900s for most Europeans and North Americans.

This pendulous shift in public opinion is resulting in significant negative health outcomes. In 2019, the World Health Organization named decreasing vaccination rates as one of their top ten largest health concerns (Scheres & Kuszewski, 2019). Dozens of outbreaks of once eradicated diseases are striking different pockets of people all over the world as a result of vaccine hesitancy (CDC, 2018). In 2020, the COVID-19 pandemic devastated communities worldwide and pushed health resources and governmental aid programs past their limits. The only economical path forward was the rapid development and widespread distribution of

vaccines, which dozens of countries spent hundreds of billions of dollars to produce in less than a year (Ella & Mohan, 2020). With the intimate threat of severe illness back on the table, one might predict that the popular sentiment would be overwhelmingly pro-vaccine. Yet, polling shows that exorbitant percentages of the population are hesitant to take the highly efficacious vaccines that our governments have rushed to produce (Sallam, 2021). Decades of highly effective vaccine misinformation, that has largely gone uncorrected, is withstanding the glaringly obvious need to vaccinate ourselves as fast as possible. The longer it takes to convince people to vaccinate, the larger the death counts and healthcare expenses grow unnecessarily (Ella & Mohan, 2020). Thoroughly understanding what has made anti-vaccination beliefs attractive and enduring will help educators shift the public opinion and ultimately save more lives.

What Makes Vaccine Misinformation So Persuasive and Long-lasting?

While a large focus in the literature has been placed on how pro-vaccine messages can improve, less emphasis has been placed on what makes anti-vaccination messages so appealing. There are many strengths of anti-vaccination misinformation and this paper will evaluate some of them now. Prior to this discussion it is important to recognize that while we label anti-vaccination messages as "misinformation" and pro-vaccine messages as "true", in everyday life these messages can be equally well presented and disseminated regardless of validity. Understanding how to present the science supporting vaccinations in a way that is more powerful than that supporting the anti-vaccination messaging is a main theme of this paper. To develop this understanding, we first examine four strengths of anti-vaccination messaging. We argue that anti-vaccination messaging is effective because it (1) aligns with people's personal values or worldviews, (2) uses convincing narratives, (3), increases fluency through images and repetition, and (4) uses digital platforms to increase exposure and create false consensus.

Personal Values and Worldviews

Attempts to dissuade public opinion about vaccines have always targeted people's values that they hold closely to their identity. Mis-informers know that patients will choose to forgo vaccines if they believe getting a vaccine is somehow contrary to a core belief. Portraying vaccination as an act against religious tenets makes misinformation extremely persuasive (Hussain et al., 2017). The science skeptic stance of many mainstream western religions make religious appeals a natural path for dissemination of anti-vaccination thought. For example, vaccines that were developed through techniques that used stem cells from embryos are largely rejected by religious groups that promote a pro-life agenda (Hussain et al, 2017). In this example, the message associates vaccines with a pro-abortion stance, which is repulsive to individuals that

hold strong pro-life values. A second example of a closely held value that has been utilized in anti-vaccination messaging is an appeal to parental responsibility to protect their children. Telling parents anecdotes of children becoming sick or developing autism after receiving dozens of vaccines will motivate parents to stop vaccinating since protecting their children is commonly central to their identity as parents (Walter, N., & Tukachinsky 2020). Lastly, the appeal to naturopathy or natural remedies among various groups in society has been an effective avenue for anti-vaccination promotion. The resurgence of clean, natural living has become an important part of many people's lives and identity. It is an easy task for anti-vaxxers to deceive this part of the population that vaccines are unnatural concoctions that should be rejected when compared to natural remedies (Kata, 2010 & 2012). In these examples, no real evidence or sound ethical argument is put forward to question the efficacy, safety, or need of vaccines, but the mere suggestion that using vaccines might be against one of these deeply held values makes these messages highly persuasive.

Anti-vaccination thought is also packaged to align with popular worldviews. For example, many people hold the popular liberalism worldview that large central governments are deleterious to civil liberties and economic prosperity. When vaccines are presented as federally developed and federally mandated, it is easy to see how people will find that contrary to this particular worldview (Hussain et al., 2017). Researchers find that this is a difficult hurdle to overcome for educators. Studies show that people will have difficulty understanding information that runs contrary to their worldviews, while readily accepting information that aligns with their worldviews (Lewandowsky et al., 2012). One of the most commonly cited worldviews that dissuades people from vaccinating is mistrust of the pharmaceutical industry (Hornsey et al., 2018). This mistrust has increased dramatically amongst the general population over the past two

decades, especially in the context of the opioid crisis that is claiming the lives of thousands each year. The fact that pharmaceutical companies have lied and used unethical means to push their products makes this worldview easy to understand and adhere to. However, no evidence of widespread manipulation or lying by pharmaceutical companies about the side effects or efficacy of the vaccines they make have been uncovered, but the association alone is enough to make vaccine misinformation compelling (Hornsey et al., 2018).

The importance of personal values and worldviews is their relationship to people's central identities. Presenting information that aligns with these values and views will produce positive emotions and easy incorporation into their knowledge schemas (Trevors et al., 2016). Information that is presented as contrary to these values and views will have the opposite effect (Trevors et al., 2016). The motivational literature demonstrates identity's prominent role in motivating our behavior (Oyserman, 2015; Oyserman et al., 2007). Therefore, if anti-vaccination movements can appeal to the values and views that make up our identity, people will ultimately be motivated to reject vaccines.

Narrative

Adherence to narrative is another factor that makes vaccine misinformation highly believable and difficult to refute. Narrative theory asserts that humans have evolved as a species with a strong reliance on story-telling due to its simple predictive power (Beach, 2010; Beach et al., 2016). In other words, being able to understand complex environments through simple, highly causal narratives allows us to make predictions about what will happen in the near future. Therefore, communication between humans is highly effective when it maintains the tenets of a good story. Examples of these tenets are strong causality and adherence to traditional story arcs

(Beach, 2010). When done well, the learner will view the new information as fluent, logical, coherent, and highly plausible, all of which are beneficial for effective learning. More traditional educational theory posits that the power of narrative is the rich sets of interconnected information that are naturally present in a good story (Kendeou & O'Brien 2014).

Studies have shown that anti-vaccination platforms are particularly adept at producing narrative arguments rather than scientific arguments (Duchsherer et al., 2020). Regardless of how much science education a reader has, the simple narrative about a son with autism who was completely healthy until he received vaccines carries an emotional message that trumps the argument based on a complex cognitive scientific explanation for why a child develops autism spectrum disorder. Consider this example from an editorial in the *Deseret News*, a news outlet backed by the LDS church in Utah whose motto is *Fighting Disinformation:*

> "My son was a typically developing toddler. He met his milestones (walking, talking, etc.) early or on time. He received his first MMR at 19 months of age. The change in him was almost immediate. He did not regress in development, but his social skills became extremely compromised. Noises became unbearable. Before the vaccination, one of his favorite "toys" was my vacuum, and he "helped" me with the household task daily. The day after his MMR vaccine, he ran from the room screaming in terror at the noise. He became obsessed with rituals and things. Food and clothing textures, previously non-issues, now were major stresses in his life." (Cindy Pokezwinski, DeseretNews, 2013)

This is purely anecdotal evidence, but it is compelling when told in this format. This story guides the reader to one obvious conclusion: the vaccine must be the cause. Our attempts to combat these types of stories with data and scientific studies are unlikely to overcome such stories despite being the truth. Stories are hard to refute, especially when told as someone's firsthand experience. Whether it is due to humans' evolutionarily preference for narrative or due to stories' highly interconnected nature, narrative is another effective vehicle of vaccine misinformation that must be taken into account when combating anti-vaccination efforts.

Fluency as a Vehicle of Persuasion

Determining whether new information is true or not can require arduous cognitive effort. The learner must determine if the information is internally consistent, supported by previously learned knowledge, offered by a trustworthy source, etc. (Schwarz, 2018). Instead of undergoing this cumbersome process hundreds of times a day, learners rely on the ease of processing as a proxy for these criteria stated above. In other words, if information is easily processed the learner will infer that it is more likely to have internal consistency, that it is more likely to fit in with current knowledge schemas, and that the source is more likely to be credible. Cognitive scientists call this ease of processing phenomena, fluency (Schwarz, 2018). Highly fluent information has a better chance of slipping through our cognitive defenses than non-fluent information. Fluency is a product of how information is presented, and misinformation about vaccine safety is largely presented in highly fluent ways. Two important strategies invoked to make vaccinate misinformation highly fluent are the use of images and repetition.

Images and The Truthiness Effect

When presented with false information accompanied by a nonprobative (a useless but thematically related) image, readers are more likely to overestimate the validity of the information than when compared to being presented with the false information alone (Newman & Zhang, 2020). This phenomenon is consistent across domains and contexts (Newman et al., 2020). Take for example the false information that was recently pushed to millions of people online through the efforts of anti-vaccination Facebook groups and religious media outlets:

"Patricia... was a volunteer in a COVID-19 vaccine study recently and had a severe adverse reaction." (BBC, 2020)

Image 1. Example image of anti-vaccination misinformation that utilizes images to increase truthiness and emotional impact. False label included to avoid misinformation potential to reader. (Source: BBC, 2020)

Although the picture does not add any validity to the statement that Patricia had a severe adverse reaction to a Covid-19 vaccine, it increases fluency of the message. Millions of people all over the globe saw this and other similar posts in 2020 (BBC, 2020). Many of those people will be tricked into accepting this information as true, even though Patricia has debunked this false claim herself. In fact, Patricia only ever received a placebo vaccine (BBC, 2020). Ironically, the use of images to increase the fluency of anti-vaccination propaganda dates well before the internet. Famously, opposition to the smallpox vaccine in the 1700s included illustrations of children with deformities allegedly caused by the vaccine (Williams 2010).

Repetition and the Illusory Truth Effect

Another simple strategy for improving the fluency of your message is to repeat it to learners over time. Learners have been found to be systematically biased to believe that repeated information is more likely to be true (Newman et al., 2020). This phenomenon, similar to the Truthiness Effect, is robust across domains of knowledge (Dechene et al., 2010). An example of

the Illusory Truth Effect that is in most people's recent memory is Donald Trump Campaign's efforts to persuade the general public that massive voter fraud has, is, and will occur in US elections. Despite not having supporting evidence of this claim, the mere repetition convinced a large number of Americans into believing massive voter fraud occurred (see Murray et al., 2020). This effect was true not only for conservative voters, but also independent and liberal voters (Murray et al., 2020). Before the internet it took more effort and money to ensure the same message reached the same person multiple times. Today, anti-vaccination influencers can ensure their targeted audience reads the same misinformation whenever they want, for free. The advent of digital echo chambers also adds additional repetition of potentially false information (Walter & Tukachinsky, 2020; Lewandowky et al., 2012). Even internet users who trust the science of vaccines are being exposed to vaccine misinformation regularly. For example, a study by the Royal Society for Public Health found that 50% of British parents of children younger than 5 years regularly encountered negative messages about vaccination on social media platforms (Burki, 2019). Whereas in the past mainstream news sources had to comply with a minimal level of fact checking, social media companies are not considered publishing agencies in the eyes of the government and are therefore not responsible for the veracity of what their users post. Efforts by these companies to censor and fact check misinformation sources has been an important strategy for many of these platforms, but these strategies runs the risk of conflicting with users first amendment.

Repeated, Multimodal Presentations Deepen Learning

Unfortunately, the strategies of repetition and adding images can do more than trick readers into overestimating validity by increasing fluency. In fact, both techniques are well

studied strategies for encouraging deep learning, or in other words, robust memory encoding. Behaviorist and Cognitive scientists have thoroughly demonstrated the improved retention rate of information when information is repeated in a spaced pattern (Pashler et al., 2007). This means that not only will misinformation about vaccines seem truer if repeated, but that it will also be more deeply encoded in the learner's memory. The caveat of the spaced repetition principle is that repetition at random, or massed repetition all at once, does not result in as robust learning as does repetition that occurs spaced out over increasing intervals (the distributed practice or spacing effect; Pashler et al., 2007; Cepeda et al., 2008; Kang, 2016). This raises the concern that these highly repeated false statements about vaccines could result in durable memories that would be more taxing to correct.

Furthermore, the use of words and images is considered multimedia learning. In today's context of social media platforms, multimodal presentations of anti-vaccination material is even more commonplace (Ma & Stahl, 2017). The use of multimedia, like repetition, also promotes deeper learning (Mayer, 2002). Theoretically the action of encoding information through multiple pathways (sight, sound, touch) results in more durable memory (Mayer, 2002). In addition, pictures have the potential to create strong emotional states which are proven to increase the learner's ability to recall that misinformation later (Kesinger & Ford, 2017). Lastly, the strong emotions provoked by multimedia misinformation about vaccines creates connection between participants (Ma & Stahl, 2017). This connection ultimately results in collaborative experiential knowledge which is held as cognitive authority by anti-vaccination groups (Ma & Stahl, 2017). In summary, the use of images not only increases believability, but it also has the potential to promote durable learning through dually coded memories and to provoke strong emotions which further strengthens the misinformation.

Mere-exposure Effect and Social Media

The power of repetition goes beyond biasing a learner's assessment of truth. Presentation of repeated information has also proven to improve the learner's affect, even when no cognitive appraisal of the information has occurred (Zajonc, 2021). For example, a study showed that a group that is exposed to five Chinese ideographs five times each (repeat-exposures condition) will have better moods than a group that is exposed to 25 Chinese ideographs one time each (Monahan et al., 2000). The exposure time can be milliseconds and this biasing still occurs. In fact, the participants do not even have to be aware that repeat exposure is occurring (Zajonc, 2021). The implication of the Mere-Exposure Effect is that media consumers will develop preferences towards what they are exposed to most often. Despite, there being more pro-vaccine individuals on Facebook than anti-vaccine individuals, a recent system-level analysis showed that anti-vaccine information is outcompeting pro-vaccine information amongst undecided individuals on Facebook (Johnson et al., 2020). Furthermore, a portion of the vaccination debate exposure that users experience is propagated by "bots" that are traced back to foreign countries who are likely trying to increase discord amongst the general US population about vaccines (Broniatowski et al., 2018). Therefore, mere exposure is one strategy that tilts the table in favor of anti-vaccination groups.

Echo Chambers and the False-Consensus Effect

The advent of digital echo chambers has several implications for the pro-vaccine/anti-vaccine information war. Sites like Facebook and Youtube, which use algorithms to connect

consumers with similar minded profiles, inevitably push users into echo chambers (Bessi et al., 2016). This is especially true for users that post about vaccines (Schidt et al., 2018). By definition, echo chambers are "environments in which a person encounters only beliefs or opinions that coincide with their own, so that their existing views are reinforced, and alternative ideas are not considered" (Oxford Languages, n.d.). Anti-vaccination echo chambers increase repetition of vaccine misinformation, which increases believability and positive affect as discussed above, but it also tricks readers into believing the misinformation is more widespread and more generally accepted than is actually true (Festinger, 1954). This is called the False-Consensus Effect. A recent study measured perceived consensus of the flu vaccine's safety on a patient's intention of getting the vaccine (Bruine de Bruin et al., 2020). As expected, they found that individuals who decide not to get the vaccine tend to overestimate the percent of people who also believe the vaccine is unsafe or ineffective (Bruine de Bruin et al., 2020).

Psychological Principles to Combat False Beliefs

Today's current models of knowledge revision or knowledge editing derive heavily from Piaget's constructivist theory of knowledge. Constructivism argues that learning is the process of making meaning of what we perceive and forming theory-coherent structures called knowledge schemas (Hyslop-Margison & Strobel, 2007). When new conceptions conflict with a student's pre-constructed schema, a cognitive correction process must occur (Sewell, 2002). The student can overwrite the pre-existing knowledge, modify the pre-existing knowledge to accommodate the new information, modify the new information to fit in with the pre-existing knowledge, or reject/ignore the new knowledge (Sewell, 2002). Sometimes this process can be achieved quite easily, but at other times it is extremely difficult.

When this correction process is unsuccessful, the student will continue in life with misconceptions embedded in their knowledge schema. It might finally be corrected during a different learning opportunity or it might continue as is. We all have hundreds, if not thousands, of misconceptions at any given time about various topics. Most of these misconceptions will never result in negative consequences, but some may. Misconceptions about the safety or efficacy of vaccines is one example that does result in serious, even fatal, consequences (CDC, 2018). According to constructivist theory, learners build knowledge schemas around vaccines based on their past experiences (Kumar & Gupta, 2009). Much of that schema might consist of inaccurate knowledge that they acquired from a parent, friend, or online. In order to correct this, the incorrect knowledge must be discarded and replaced with correct conceptions (Kumar & Gupta, 2009). The amount of accommodation required would depend on the number of misconceptions that make up the overall knowledge schema (Kumar & Gupta, 2009).

If we accept the constructivist view of knowledge construction and editing, then what educators need to know is how to foster the accommodation process so that accurate mental models of vaccines can be formed by misinformed patients. The conceptual change literature has sought to answer this question and several models of conceptual change have been proposed that provide insights into what exactly is needed to update our knowledge schema. Posner's Conceptual Change Model (CCM) and the resulting research in refutation texts are particularly pertinent to the vaccine topic (Yazbec et al., 2019).

Posner's Conceptual Change Model

Researchers interested in describing the process of accommodation debated if the "naive" misconceptions were slowly replaced piece by piece over many learning experiences, or if there was a single moment of revolution in which the erroneous schema is corrected (Yazbec et al., 2019). Traditional constructivist theory implies that knowledge schemas are organized in theory-based components. Therefore, the accommodation process requires a paradigm shift approach, or else it would risk having conflicting knowledge within the same schemas at any given time (Özdemir & Clark, 2007). With this in mind, Posner et al. (1982) proposed the elements needed to bring about this paradigm shift. They proposed that first a learner must become dissatisfied with the naive knowledge they currently possess. Then, the correct information must be presented to the learner in an intelligible format. In other words, the truth must make sense to the learner. Thirdly, the new knowledge must pass a basic plausibility test. This means that it checks out with other beliefs that the learner holds. Lastly, the learner must perceive some kind of value to going through the process of accommodation (Posner et al., 1982). The new knowledge must be seen as useful or beneficial to the learner. Otherwise, they will have no motivation to apply

the cognitive effort needed to update their schema. Posner et al. (1982) hypothesized that if these four conditions were met, successful conceptual change will occur.

To illustrate Posner's model, we can take an anti-vaccination parent as an example. Suppose a parent holds the naive belief that the influenza vaccine causes the flu. This parent might become dissatisfied with this belief if their child misses a week of school each winter because they consistently contract the virus. Then, at the pharmacy this parent might speak to a healthcare professional who explains that the influenza vaccine is made up of inactivated pieces of the virus which are incapable of causing the illness itself. This true knowledge will hopefully make sense to the parent and fit in with their other beliefs about viruses and the immune system i.e. it is intelligible and plausible. Lastly, the parent's desire for their child to not fall ill each winter may provide enough motivation to accommodate their knowledge schema to fit this new information.

A common pitfall when evaluating learning within the CCM framework is that from the learner's perspective, the "naive" understanding could just as easily be the correct conception being replaced by a misconception. Take for example, a parent who has correctly learned about the safety and efficacy of vaccines. Then, their child is diagnosed with autism shortly after receiving a round of childhood vaccines. The parent then reads on social media that there are many parents with similar experiences who cite research studies that indicate a causal relationship between vaccines and ASD. In this situation the naive knowledge is actually the correct conception, and the new information being presented is what will lead to the misconception. This illustrates that learners can just as easily become dissatisfied with true conceptions while misconceptions can be presented as equally intelligible, plausible, and useful as truth.

Refutation Texts

From the conceptual change framework, a new educational tool was developed to help fast track the conceptual change educators are striving to achieve. This tool was coined refutation texts (RT) by Maria & MacGinitie (1987). RTs seek to promote schematic changes by presenting misconceptions, refuting them, and then providing the correct information all in the same text (Maria & MacGinitie,1987). This is opposed to traditional or explanatory texts which focus on explaining the correct conception without acknowledging related misconceptions. Consider this RT about vaccine importance:

> "Some people believe that vaccines are unnecessary in modern times because most serious illnesses are already eradicated. This belief, however, is inaccurate and contradicts the scientifically accepted facts. Vaccines are still necessary in modern times. If diseases like measles, meningitis, polio, rubella, and whooping cough seem uncommon – perhaps you've never even heard of them – this is because vaccines are doing their job. Many parents today may be too young to remember the toll these diseases took before vaccines. Before the vaccination program in the US was developed over 50 years ago, life used to be especially brutal for children with huge numbers of child fatalities from the diseases mentioned above. The US vaccination program has been one of the most successful health campaigns in history in terms of lives saved." (Kessler et al., 2019)

In this example, a misconception about the societal need for vaccines is presented to the reader. This is followed by a refutation sentence and then a brief explanation for why vaccines are important. Theoretically, by refuting the misconception the learner will become dissatisfied with what they previously learned. Then, they are taught the truth in a plausible and intelligible format. Hence, RTs are a systematic way of achieving knowledge schema updates for learners with misconceptions.

Dozens of studies over the last 40 years have demonstrated the effectiveness of RTs when compared to explanatory texts in instigating conceptual change (Maria & MacGinitie, 1987; Alvermann & Hynd, 1989; Mason et al., 2008; Kowalski & Taylor, 2009; Broughton et al., 2010; Cameron et al., 2013; Kendou et al., 2014; Trevors, 2016; Thacker et al., 2019). Many of the early studies that demonstrated superiority of RTs were in the context of science education. Hynd and Alvermann's (1986) study which divided physics students into groups, some receiving a refutation text about projectile motion and some receiving an explanatory text about projectile motion, is a classic example of early refutation style text studies. In their study, students who were exposed to the refutation style text displayed less misconceptions on post-test than did those exposed to explanatory texts. More recently, RTs have moved outside the education domain and have been applied to socio-political misconceptions such as vaccine safety. The power of RTs in these domains are less clear cut (Zengilowski et al., 2020). For example, Pulviano et al. (2018) found that parents who were presented with refutation style (facts vs myth) information about vaccines walked away with stronger misconceptions when tested immediately after and at one week after the intervention when compared to a control group. Yet, in another study from 2020, Trevors and Kendeou found that RTs about vaccines, with or without emotional content, improved learning. In light of these conflicting results, current consensus deems RTs are superior to explanatory texts in several educational domains, while more research is needed to justify their use in other domains such as patient education about vaccines (see critical review of literature by Zengilowski et al., 2020).

RTs are by no means the only educational tool that has been developed to help foster deep learning in learners with misconceptions. This paper focuses on RTs for various reasons. First, interventions using Refutations Texts are easily scalable. Once a vaccination refutation text

has shown empirical superiority to its traditional counterpart, it could theoretically be widely distributed to patients all over the country. Secondly, interventions using RTs rely on the text to induce conceptual change, not the teacher. This means that little training is necessary for healthcare workers to be able to effectively use them with their patients. This is particularly important for a topic like anti vaccination because most healthcare workers have no formal training in teaching. Likewise, RTs are easily publishable on social media platforms, where the majority of the discussions on this topic takes place. The promise of RTs is that if researchers can find a way to make them as effective as they have proven to be in the education domain, they could be a low-cost intervention that would produce robust health outcomes. In order for this to become a reality, we must first understand why RTs in their current form do not always work for the vaccination domain, which will require a reflection on its theoretical underpinnings. Attempts to understand when and why RTs were successful exposed several weaknesses of Posner's CCM that are important to address in order to improve educators' chances at overcoming misinformation.

Why Might Refutation Texts Fall Short of Correcting Vaccine Misinformation?

First, the conceptual change model that underlies the refutation text literature makes strong assumptions that are not supported by the empirical evidence, namely, the assumptions that (a) lasting learning can occur in a single shot, and (b) accommodation results in the erasure of old conceptual structures and prior conflicting information. Rather, both cognitive and behavioral research has shown that robust learning rarely happens in one shot (Ebbinghaus, 1885; Underwood & Keppel, 1962). Repetition, especially spaced repetition, is a fundamental

component of successful long-term learning (Wogan & Waters, 1959; Bromage & Mayer, 1986). Therefore, the notion that one refutation text at one point in time will result in an enduring change of the learner's mental model about vaccines does not coincide with accepted cognitive psychology theory. And rather than "erasing" old conflicting information, we know from the literature that humans readily hold and endorse conflicting information all the time, and even after thorough correction, the old information can return under certain conditions (Özdemir& Clark, 2007). Actually, animal and human studies have shown that in some instances, the old knowledge spontaneously recovers (See Payne 1987 for review of spontaneous recovery). This was first noted by Pavlov in his salivating dog experiments. When the dog was conditioned to salivate to a particular tone and then reconditioned to salivate to a second tone, instead of forgetting the first tone, the association actually strengthened with time (Wheeler, 1995). The same occurs for humans. Word association studies find that subjects will still cling to old associations (A-B) even after that association undergoes extinction and is replaced with a different word association (A-C) (Underwood, 1948).

In light of these shortcomings, it is apparent that successful unrooting of false beliefs will require more than one refutation text in most situations. False beliefs about vaccines appear to be one of those situations (Nyhan & Reifler, 2015). That is not to discredit the success and power that RTs have had in many domains;iIt merely points out that conceptual change models of knowledge correction are not taking into account everything we now know about learning. Because of this, a new model of knowledge updating has been proposed that is more consistent with the empirical research and explains the outcomes of RTs more clearly. This model is the Knowledge Revision Components Framework.

KReC Framework: An Alternative Model for Understanding Knowledge Revision

Rather than viewing conceptual change as an erase and replace process, the KReC model proposes that misconceptions and corrections are encoded separately and must compete for future activation. Additionally, the KReC model does not adhere to the assumption that knowledge schemas are stored in theory-based components, which is a foundational assumption of Posner's conceptual change model (Kendeou & O'Brien, 2014). Instead, they build on the premise that information is processed and permanently stored in our memory as a loosely interconnected network that allows for recall of the information at contextually appropriate times (Kendeou & O'Brien, 2014). Under this model, when the targeted knowledge network is activated, the corrections and misconceptions are co-activated. The goal of conceptual change should be to ensure that the correction becomes more strongly tied into the knowledge network than the misconception. The five components of the KReC model are as follows: automatic encoding, passive activation, co-activation, integration, and competing activation. In short Kendeou et al. (2014) argues that information is automatically processed and encoded into our memory at the time of presentation. When we are in a context that requires this information, passive activation brings what we previously learned about a topic into our working memory (Kendeou & O'Brien, 2014). When old-misinformation is brought into the working memory with new-correct information the principle of co-activation has occurred. This will result in a cognitive dissonance that will require an adjustment to the knowledge structure (Kendeou et al., 2017). Assuming integration does occur, the learner will now have both pieces of information tightly bound in one memory network.

In summary, early models of conceptual change, such as Posner et al.'s CCM, succeeded in proposing useful conditions for knowledge revision to occur and developing effective

educational tools, namely RTs. However, the assumptions about the nature of knowledge

schemas which emphasized a paradigm shift and an erase and replace model of knowledge

revision hindered the application of RTs with well supported cognitive strategies. The KReC

framework avoids this pitfall and adequately describes the necessary but insufficient power of

RTs to cause co-activation and integration. Within this new framework, the importance of

learning strategies that strengthen the activating potential of the correct information is apparent.

Unfortunately, the activating potential of misinformation about vaccines in anti-vaccine

individuals is extremely strong because of the strategies discussed in the previous sections. To

outcompete these false beliefs, pro-vaccine material needs to be presented in a way that is at least

as compelling, and hopefully more compelling than the information it is refuting. Bridging the

gap in persuasiveness is imperative to keep vaccination rates high even during times when the

risk of disease is not obvious to the general population. The remainder of this paper will focus on

strategies that can be incorporated into RTs to help even the playing field for pro-vaccination

campaigns.

Spaced Repetition

The first technique that pro-vaccines messages should employ with RTs is spaced

repetition. This requires abandoning the notion that using a RT once in the doctor's office is

sufficient to correct myths about vaccines. Beyond the doctor's office, patients will need

reminders of what they learned from the refutation text via digital platforms e.g., follow up

emails, text messages, social media. For example, a pediatric clinic could use RTs in the office

and also direct their patients to mainstream pro-vaccine pages on social media to help strengthen

their new knowledge over time. The more a patient sees pro-vaccine information, the more likely

they are to consider it true. In essence, pro-vaccine messaging also needs to apply the Illusory Truth Effect, despite actually being true. Furthermore, educators and healthcare professionals should revisit the vaccination topic frequently when the patient is seen in the future to strengthen the corrected memory pathway, but also to identify when the initial teaching intervention has failed. This can be done with the repetition of a refutation text. While mere repetition is useful, applying true spaced repetition would be an even more powerful learning strategy. Many studies have already shown the value of adding spacing in medical education (see Versteeg et al., 2020 for review). This could also be facilitated through digital platforms in which progressively longer spaced intervals can be easily incorporated within a refutation text framework. Gamification of patient education is an example of this which has already proved successful (Kerfoot et al, 2014).

Increasing Exposure and Countering Echo Chambers

As discussed, vaccine misinformation uses social media's echo chambers to create a metacognitive experience that increases believability. The more a learner encounters a myth about vaccines, the more fluent the concept becomes. Because of the nature of echo chambers, learners are prone to think that false information about vaccines is coming from many different sources therefore it must be true (Lewandowsky et al., 2012). These same concepts should be incorporated into pro-vaccine efforts. Broadening the use of RTs beyond doctor's offices and the CDC's website is one way in which this could be accomplished. This requires creative strategies to leverage social media platforms in favor of pro-vaccine campaigns instead of anti-vaccine campaigns. Buying up ad space on different platforms is one way to accomplish this but using pro-vaccine "bots" is also a strategy that could work to improve agreement on vaccines just as well as it works to promote vaccine discord. In addition to digital platforms, vaccine safety

messages should be presented in many different environments including schools, parks, and public events. The more places patients see pro-vaccine RTs, the less they will overestimate the general acceptance of vaccine misinformation that is caused by the false-consensus effect discussed earlier. Lastly, combatting the effects of online echo chambers is a significant challenge. Pro-vaccine echo chambers also exist on social media platforms, which is great for maintaining strong support for vaccine use for people in those groups, but the existence of echo chambers in themselves restricts a mixing of ideas that is important for societal knowledge building (Nguyen, 2020). Requesting media platforms, which profit from echo chambers, to inform consumers of the risk of polarization that comes with the use of their websites is one approach to helping people avoid them in the first place. Since echo chambers are not desirable tools for refuting anti-vaccination material, our focus should be on breaking down echo chambers whenever possible.

Multimodal Teaching

Pro-vaccine efforts are capable of being as equally illustrative and image based as anti-vaccination efforts. Studies have shown that doctors have more success changing opinions about vaccines when images of children with preventable diseases are included into the presentation rather than graphs from randomized controlled trials (Horne et al., 2015). As mentioned, cognitive psychology promotes mutlimodal teaching styles for improved comprehension and retention (Mayer, 2002). Anti-vaccination material is commonly using a combination of texts, videos, and pictures to improve comprehension of misinformation and to mislead their audience. The same strategies should be applied to pro-vaccination material. Take for example this FDA message about the safety of vaccines:

> "A vaccine containing 0.01% thimerosal as a preservative contains 50 micrograms of thimerosal per 0.5 mL dose or approximately 25 micrograms of mercury per 0.5 mL dose. For comparison, this is roughly the same amount of elemental mercury contained in a 3 ounce can of tuna fish." (Centers for Biologics Evaluation and Research)

This is an effective argument that has been presented in an ineffective way. Readers struggle with conceptualizing micrograms and decimal percentages. A picture or animation that helps the audience conceptualize these quantities compared to everyday items like a can of tuna would improve the understanding and retention of these types of messages. Adding these images or illustrations to RTs was shown to be advantageous in a 2016 study by Danielson et al. In their study they compared conceptual change results for students randomly assigned to RT or RT + augmenting factors (illustrations). Another study by Mason et al. in 2017 showed less robust results when adding images to RTs. Clearly, the potential for improving conceptual change with images is real, but more research is needed to help clarify when and how they can be used to augment RTs. One challenge that public health officials are struggling with during the COVID-19 pandemic is convincing the general public of the real risk of infection. In Horne et al., (2015) study it was easy to show pictures of children with measles to help convince parents to consent to the MMR vaccine. For many people, COVID-19 is an invisible disease. The general public does not see the thousands of chest x-rays with lung damage, or the MRIs of brain bleeds, or the patients intubated for weeks in the ICU that the healthcare community are seeing on a daily basis. Combining these images with relevant RTs would likely improve public health efforts.

Worldviews and Personal Values

Connecting the importance of vaccinations to prominent worldviews or tightly held values is an important way that truths about vaccines can outcompete myths about vaccines.

Doing has been shown to lower the learner's skepticism of vaccine importance and improves

assimilation of true information (Lewandoski et al., 2012). To build off the previous example

about large central governments, pro-vaccination campaigns could easily counter this objection

by connecting vaccine importance to American safety or American ingenuity which are two

related and common worldviews held by US citizens. Furthermore, connecting the importance of

vaccines to worldviews such as those endorsed by national populist movements that are

increasingly popular might prove extremely effective. The COVID-19 vaccines, for example,

could be presented as a defense for the common worker and a way to reduce restrictions on

social freedoms. This would align with popular worldviews that the government should work for

the common people (not the elite) and that governmental restrictions on individual freedoms

should be as minimal as possible. The main purpose of this is not to validate or promote specific

worldviews, but merely to help people realize that being vaccinated actually fits into most deeply

ingrained worldviews. Worldviews are not exclusively useful to the uptake of anti-vaccination

information. Presenting pro-vaccination information in a way that aligns with identity,

contributing worldviews, or values has shown to improve knowledge revision (Lewandoski et

al., 2012). Caution is advised when applying this strategy because promoting worldviews related

to patriotism can quickly result in extreme nationalism. This is problematic for many reasons, the

least of which is that vaccinations are developed to fight global diseases, and therefore it is

important that all people are considered for vaccine distribution, not just Americans.

Incorporating this world-view alliance strategy into RTs could potentially be very beneficial for

improving their usefulness in today's socio-cultural context. Consider the following example:

> "Many people believe that efforts by the government to require COVID-19 vaccination
> violates civil liberties and state's rights. While it may appear to be the case, requiring
> widespread vaccination is actually protecting citizens' health and also their financial
> well-being. In fact, the sooner the majority of our population is vaccinated the sooner

regular commerce can continue and the sooner tax dollars can be saved from paying for costly hospital bills. Ultimately, requiring COVID-19 vaccines is the fastest way to help small businesses increase their revenue and limit the need for exorbitant relief bills that require tax dollars."

This refutation text is similar to a normal refutation text correcting the misconception that local and federal governments should not be pushing for widespread vaccination, but it does so in the framework of a common conservative worldview. Little research has been done comparing the effectiveness of RT vs RT + worldview messaging and is needed to help public health officials understand how to use it effectively.

Narrative

The next teaching strategy that should be employed to help combat false beliefs about vaccines is narrative teaching. As discussed previously, the use of highly causal, highly interconnected storytelling is an effective way to promote learning. Whether this is due to evolutionary explanations as the narrative learning theory posits or due to the rich set of interconnections that causal stories innately have, the literature indicates that new information is more likely to stick and be less affected by previously learned knowledge when it is presented in a narrative format (Kendeou & O'Brien, 2014; Beach & Bissell 2016). A strong argument for narrative structure also comes from the constructivist literature, which suggests that correcting an incorrect mental model will fail unless an equally coherent and easy to understand mental model is offered as a replacement i.e., learners prefer an incorrect understanding of the world over a complex one (Lewandowski et al., 2012). Narratives provide a coherent and easily digestible alternative to the misinformation even when the truth is not simple. The introduction of this paper serves as an example for how narrative can be used to promote the safety of vaccines. It

presents a counter story to the one that was shared in the *Deseret News*, with a set of events that are equally causal and easy to understand. The true story of Wakefield's research has the added strength of being verifiable, which is not true for anecdotal stories of the MMR vaccine causing ASD. Additionally, accepting the alternative narrative gives the reader an easy explanation for why they were fooled in the first place, making it easier to accept they were wrong. All of these effects will ultimately help the newly acquired truth about vaccines outcompete the old information for activation when the topic arises in the future. Incorporation of this strategy into RTs is easily done and has already been looked at in a handful of studies, which have found it beneficial as expected (Lassondre et al., 2016).

A Practical Solution: Leveraging multiple Psychological Principles to Enhance Refutation Texts

While the literature supports the use of all the above strategies on their own, our hypothesis is that incorporating them into RTs is an easy way to allow educators and non-educators to tap into these powerful psychological principles. The pandemic and surge of parents refusing childhood vaccinations are both high risk situations that call for quick action to stem the harm of anti-vaccination efforts. With this in mind, it is reasonable to consider combining multiple psychological principles to enhance the impact of RTs to the fullest. For example, presenting a refutation text + narrative to vaccine-hesitant parents in a repeated-over-time fashion (instead of a single one-off reading of the text) will likely improve learning outcomes. We expect the same to be true for combining any of the principles we have presented in this paper. More studies should be done to test the effectiveness of enhanced RTs in the vaccine domain. Any enhancements that do improve outcomes should be adopted into the pro-vaccine messaging. Furthermore, there are other psychological principles that have already been proven to help leverage RTs that have not been covered in this paper thus far, which we will cover now for completeness of the topic.

While there are only a few studies that have tested these types of enhancements to RTs, some have shown beneficial effects. For example, refuting the misconception in a more polite, or soft, language is equally effective as using standard, direct, language (Schroeder, 2016). This is thought to be particularly true for controversial subjects such as vaccine safety. In Schroeder's experiment they presented traditional RTs and soft RTs to different groups of students and found the soft RTs to have an equal effect size for changing students' minds about myths related to genetically modified foods. Since the vaccine topic is highly polarized and identity driven,

softening the language in RTs should help bypass some of the aversion learners experience when

they are told they are wrong about something that is important to them. Another enhancement

that has proven beneficial is adding persuasive post-RT text. One study found that the addition of

a persuasive text resulted in more robust conceptual change than the standard RT alone (Thacker

et al., 2020). In their intervention the addition of a text that outlined the advantages of genetically

modified food resulted in more positive attitudes towards GMFs and fewer misconceptions.

These are just two examples of enhancements to RTs that already have support in the literature

and could be tacked onto any RT intervention.

Conclusion

In this paper we have discussed the history and importance of the anti-vaccination movement. Using several educational psychology perspectives we examined what aspects make false information about vaccines difficult to overcome. These aspects include the connection to identity defining worldviews or values, the use of narrative format, the use of strategies that promote high fluency and deep learning, the use of the mere-exposure effect and the false-consensus effect, and the use of echo-chambers. Decades of conceptual change research which resulted in the CCM and RTs have improved public debiasing efforts, but ultimately are not enough to get or keep vaccination rates at herd immunity levels. The new KReC model offers a cognitive psychology informed perspective to conceptual change and is an important improvement to our understanding of how to combat misinformation. We argue that well understood teaching techniques such as spaced repetition, multimedia, narrative, and worldview alignment should be incorporated into refutation efforts immediately to help scientific information outcompete misinformation for activation. Furthermore, researchers should continue to test the refutation text enhancing strategies promoted in this paper, and continue to search for and study other additives to help in this important area of public education.

References

Alazraki, M. (2011). The autism vaccine fraud: Dr. Wakefield's costly lie to society. *Daily Finance*.

Beach, L. R., & Bissell, B. L. (2016). *A new theory of mind: The theory of narrative thought*. Cambridge Scholars Publishing.

Beach, L. R. (2010). *The psychology of narrative thought: How the stories we tell ourselves shape our lives*. Xlibris Corporation.

Bessi, A., Zollo, F., Del Vicario, M., Puliga, M., Scala, A., Caldarelli, G., ... & Quattrociocchi, W. (2016). Users polarization on Facebook and Youtube. PloS one, 11(8), e0159641.

Bromage, B. K., & Mayer, R. E. (1986). Quantitative and qualitative effects of repetition on learning from technical text. *Journal of Educational Psychology, 78*(4), 271–278.

Broniatowski, D. A., Jamison, A. M., Qi, S., AlKulaib, L., Chen, T., Benton, A., Quinn, S. C., & Dredze, M. (2018). Weaponized Health Communication: Twitter Bots and Russian Trolls Amplify the Vaccine Debate. American journal of public health, 108(10), 1378–1384.

Bruine de Bruin, W., Galesic, M., Parker, A. M., & Vardavas, R. (2020). The role of social circle perceptions in "false consensus" about population statistics: Evidence from a national flu survey. Medical Decision Making, 40(2), 235–241.

Burki, T. (2019). Vaccine misinformation and social media. The Lancet Digital Health, 1(6), e258-e259.

Cameron KA, Roloff ME, Friesema EM, Brown T, Jovanovic BD, Hauber S, Baker DW. Patient knowledge and recall of health information following exposure to "facts and myths" message format variations. 2013. Patient Educ Couns, 92(3): 381–387.

Caulfield, T., Marcon, A. R., & Murdoch, B. (2017). Injecting doubt: responding to the

    naturopathic anti-vaccination rhetoric. *Journal of Law and the Biosciences*, *4*(2), 229-

    249.

Center for Biologics Evaluation and Research. (n.d.). *Thimerosal and Vaccines*. U.S. Food and

    Drug Administration. https://www.fda.gov/vaccines-blood-biologics/safety-availability-

    biologics/thimerosal-and-vaccines.

Cepeda, N. J., Vul, E., Rohrer, D., Wixted, J. T., & Pashler, H. (2008). Spacing effects in

    learning: A temporal ridgeline of optimal retention. Psychological science, 19(11), 1095-

    1102.

Deer, B. (2011). How the case against the MMR vaccine was fixed. *Bmj*, *342*.

Duchsherer, A., Jason, M., Platt, C. A., & Majdik, Z. P. (2020). Immunized against science:

    Narrative community building among vaccine refusing/hesitant parents. *Public*

    Understanding of Science, *29*(4), 419-435.

Ebbinghaus, H. (1885). *Über das gedächtnis: untersuchungen zur experimentellen psychologie*.

    Duncker & Humblot.

Ecker, U. K., Swire, B., & Lewandowsky, S. (2014). Correcting misinformation—A challenge

    for education and cognitive science.

Ella, K. M., & Mohan, V. K. (2020). Coronavirus vaccine: Light at the end of the tunnel. *Indian*

    pediatrics, *57*, 407-410.

Ernst E. (2001). Rise in popularity of complementary and alternative medicine: reasons and

    consequences for vaccination. *Vaccine*, *20 Suppl 1*, S90–S89.

Ferrero, M., Hardwicke, T. E., Konstantinidis, E., & Vadillo, M. A. (2020). The effectiveness of refutation texts to correct misconceptions among educators. *Journal of experimental psychology: applied*.

Festinger, L., Riecken, H., & Schachter, S. (1956). When prophecy fails. Minneapolis, MN, US.

Festinger, L. (1954). A theory of social comparison processes. Human relations, 7(2), 117-140.

Geddes, A. M. (2006). The history of smallpox. *Clinics in dermatology*, *24*(3), 152-157.

Godlee, F. (2011). The fraud behind the MMR scare.

Hamilton, S. (2002). From Haircutters To Hemochromatosis: A History of Bloodletting. *History Of Medicine Days*, *1*.

Horne, Z., Powell, D., Hummel, J. E., & Holyoak, K. J. (2015). Countering antivaccination attitudes. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(33), 10321–10324.

Hornsey, M. J., Harris, E. A., & Fielding, K. S. (2018). The psychological roots of anti-vaccination attitudes: A 24-nation investigation. *Health Psychology*, *37*(4), 307.

Hussain, A., Ali, S., Ahmed, M., & Hussain, S. (2018). The anti-vaccination movement: a regression in modern medicine. *Cureus*, *10*(7).

Hynd, C., & Alvermann, D. E. (1986). The role of refutation text in overcoming difficulty with science concepts. *Journal of Reading*, *29*(5), 440-446.

Hyslop-Margison, E. J., & Strobel, J. (2007). Constructivism and education: Misunderstandings and pedagogical implications. The Teacher Educator, 43(1), 72-86.

Ibelema, M., & Powell, L. (2001). Cable television news viewed as most credible. Newspaper Research Journal, 22(1), 41-51.

Johnson, N. F., Velásquez, N., Restrepo, N. J., Leahy, R., Gabriel, N., El Oud, S., ... & Lupu, Y. (2020). The online competition between pro-and anti-vaccination views. *Nature*, *582*(7811), 230-233.

Johnson HM, Seifert CM. Sources of the continued influence effect: when misinformation in memory affects later inferences. J Exp Psychol Learn Mem Cogn. 1994;20(6): 1420–1436.

Kang, S. H. (2016). Spaced repetition promotes efficient and effective learning: Policy implications for instruction. *Policy Insights from the Behavioral and Brain Sciences*, *3*(1), 12-19.

Kata, A. (2010). A postmodern Pandora's box: anti-vaccination misinformation on the Internet. *Vaccine*, *28*(7), 1709-1716.

Kata, A. (2012). Anti-vaccine activists, Web 2.0, and the postmodern paradigm–An overview of tactics and tropes used online by the anti-vaccination movement. *Vaccine*, *30*(25), 3778-3789.

Kendeou, P., & O'Brien, E. J. (2014). The Knowledge Revision Components (KReC) framework: Processes and mechanisms.

Kendeou, P., Butterfuss, R., Van Boekel, M., & O'Brien, E. J. (2017). Integrating relational reasoning and knowledge revision during reading. *Educational Psychology Review*, *29*(1), 27-39.

Kensinger, E. A., & Ford, J. H. (2016). Emotion Processing and Emotional Memory Encoding. *Cognitive Neuroscience of Aging: Linking Cognitive and Cerebral Aging*.

Kerfoot, B. P., Turchin, A., Breydo, E., Gagnon, D., & Conlin, P. R. (2014). An online spaced-education game among clinicians improves their patients' time to blood pressure control:

a randomized controlled trial. Circulation: Cardiovascular Quality and Outcomes, 7(3), 468-474.

Kessler, E.D., Braasch, J.L.G., Kardash, C.M., (2019). Individual Differences in Revising (and Maintaining) Accurate and Inaccurate Beliefs About Childhood Vaccines. To appear in Discourse Processes, 2019.

Kowalski P, Taylor AK. The effect of refuting misconceptions in the introductory psychology class. Teach Psychol. 2009;36(3): 153–159.

Kumar, R., & Gupta, V. K. (2009). An introduction to cognitive constructivism in education. *Journal of Indian Education*, *35*(3), 39-45.

Lassonde, K. A., Kendeou, P., & O'Brien, E. J. (2016). Refutation texts: Overcoming psychology misconceptions that are resistant to change. Scholarship of Teaching and Learning in Psychology, 2(1), 62.

Lewandowsky, S., Ecker, U. K., Seifert, C. M., Schwarz, N., & Cook, J. (2012). Misinformation and its correction: Continued influence and successful debiasing. *Psychological science in the public interest*, *13*(3), 106-131.

Ma, J., & Stahl, L. (2017). A multimodal critical discourse analysis of anti-vaccination information on Facebook. *Library & Information Science Research*, *39*(4), 303-310.

Maria, K., & MacGinitie, W. (1987). Learning from texts that refute the reader's prior knowledge. *Literacy Research and Instruction*, *26*(4), 222-238.

Mason, L., Baldi, R., Di Ronco, S., Scrimin, S., Danielson, R. W., & Sinatra, G. M. (2017). Textual and graphical refutations: Effects on conceptual change learning. Contemporary Educational Psychology, 49, 275-288.

Mayer, R. E. (2002). Multimedia learning. In *Psychology of learning and motivation* (Vol. 41, pp. 85-139). Academic Press.

MILLARD C. K. (1948). The end of compulsory vaccination. *British medical journal*, *2*(4589), 1073–1075. https://doi.org/10.1136/bmj.2.4589.1073

Murray, S., Stanley, M., McPhetres, J., Pennycook, G., & Seli, P. (2020). " I've said it before and I will say it again": Repeating statements made by Donald Trump increases perceived truthfulness for individuals across the political spectrum.

Newman, E.J. & Zhang, L. (2020). Truthiness: How nonprobative photos shape belief. Greifeneder, R., Jaffé, M., Newman, E.J., & Schwarz, N. (Eds.) (in press). The psychology of fake news: Accepting, sharing, and correcting misinformation. London, UK: Routledge.

Nguyen, C. T. (2020). Echo chambers and epistemic bubbles.

Nissani, M., & Hoefler-Nissani, D. M. (1992). Experimental studies of belief dependence of observations and of resistance to conceptual change. *Cognition and Instruction*, *9*(2), 97-111.

Nyhan, B., & Reifler, J. (2015). Does correcting myths about the flu vaccine work? An experimental evaluation of the effects of corrective information. Vaccine, 33(3), 459-464.

Oxford Languages. (n.d.). In *Oxford Languages dictionary.* Retrieved December 20, 2020, from https://languages.oup.com/google-dictionary-en/

Oyserman, D., Fryberg, S. A., & Yoder, N. (2007). Identity-based motivation and health. *Journal of personality and social psychology*, *93*(6), 1011.

Oyserman, D. (2015). Identity-based motivation. *Emerging trends in the social and behavioral sciences: An interdisciplinary, searchable, and linkable resource*, 1-11.

Özdemir, G., & Clark, D. B. (2007). An overview of conceptual change theories. *Eurasia Journal of Mathematics, Science and Technology Education*, *3*(4), 351-361.

Pashler, H., Rohrer, D., Cepeda, N. J., & Carpenter, S. K. (2007). Enhancing learning and retarding forgetting: Choices and consequences. Psychonomic bulletin & review, 14(2), 187-193.

Payne, D. G. (1987). Hypermnesia and reminiscence in recall: A historical and empirical review. *Psychological Bulletin*, *101*(1), 5.

Plotkin, S. A., & Buser, F. (1985). History of RA27/3 rubella vaccine. *Clinical Infectious Diseases*, *7*(Supplement_1), S77-S78.

Pluviano, S., Watt, C., Ragazzini, G., & Della Sala, S. (2019). Parents' beliefs in misinformation about vaccines are strengthened by pro-vaccine campaigns. Cognitive processing, 20(3), 325-331.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science education, 66(2), 211-227.

Ramsay, C., Kull, S., Lewis, E., & Subias, S. (2010). Misinformation and the 2010 election: A study of the US electorate.

Sallam, M. (2021). COVID-19 Vaccine Hesitancy Worldwide: A Concise Systematic Review of Vaccine Acceptance Rates. *Vaccines*, *9*(2), 160.

Scheres, J., & Kuszewski, K. (2019). The Ten Threats to Global Health in 2018 and 2019. A welcome and informative communication of WHO to everybody. *Zeszyty Naukowe Ochrony Zdrowia. Zdrowie Publiczne i Zarzadzanie*, *17*(1), 2-8.

Schmidt, A. L., Zollo, F., Scala, A., Betsch, C., & Quattrociocchi, W. (2018). Polarization of the vaccination debate on Facebook. *Vaccine*, *36*(25), 3606-3612.

Schroeder, N. L. (2016). A preliminary investigation of the influences of refutation text and instructional design. Technology, Knowledge and Learning, 21(3), 325-340.

Schwarz, N. (2018). *Of fluency, beauty, and truth: Inferences from metacognitive experiences.* In J. Proust & M. Fortier (Eds.), *Metacognitive diversity: An interdisciplinary approach* (p. 25–46). Oxford University Press.

Sewell, A. (2002). Constructivism and Student Misconceptions. Australian Science Teachers Journal, 48(4), 24.

Smith, M. J. (2015). Promoting vaccine confidence. *Infectious Disease Clinics*, *29*(4), 759-769.

Thacker, I., Sinatra, G. M., Muis, K. R., Danielson, R. W., Pekrun, R., Winne, P. H., & Chevrier, M. (2020). Using persuasive refutation texts to prompt attitudinal and conceptual change. Journal of Educational Psychology, 112(6), 1085.

Trevors, G., & Kendeou, P. (2020). The effects of positive and negative emotional text content on knowledge revision. *Quarterly Journal of Experimental Psychology*, *73*(9), 1326-1339.

Trevors, G. J., Muis, K. R., Pekrun, R., Sinatra, G. M., & Winne, P. H. (2016). Identity and epistemic emotions during knowledge revision: A potential account for the backfire effect. *Discourse Processes*, *53*(5-6), 339-370.

Underwood, B. J., & Keppel, G. (1962). One-trial learning?. Journal of Memory and Language, 1.

Underwood, B. J. (1948b). "Spontaneous recovery" of verbal associations. *Journal of Experimental Psychology*, *38*, 429–439.

Van Raemdonck, N. (2019). The Echo Chamber of Anti-Vaccination Conspiracies: Mechanisms of Radicalization on Facebook and Reddit. *Institute for Policy, Advocacy and Governance (IPAG) Knowledge Series, Forthcoming*.

Versteeg, M., Hendriks, R. A., Thomas, A., Ommering, B. W., & Steendijk, P. (2020). Conceptualising spaced learning in health professions education: A scoping review. Medical education, 54(3), 205-216.

Vosniadou, S., Vamvakoussi, X., & Skopeliti, I. (2008). The framework theory approach to the problem of conceptual change. *International handbook of research on conceptual change*, 3-34.

Walter, N., & Tukachinsky, R. (2020). A meta-analytic examination of the continued influence of misinformation in the face of correction: How powerful is it, why does it happen, and how to stop it?. *Communication Research*, *47*(2), 155-177.

Wheeler, M. (1995). Improvement in Recall Over Time Without Repeated Testing: Spontaneous Recovery Revisited. Journal of Experimental Psychology. Learning, Memory, and Cognition, 21(1), 173–184.

Williams, G. (2010). *Angel of death: the story of smallpox*. Springer.

Wogan, M., & Waters, R. (1959). The Role of Repetition in Learning. The American Journal of Psychology, 72(4), 612-613. doi:10.2307/1419511

Wolfe, R. M., & Sharp, L. K. (2002). Anti-vaccinationists past and present. *BMJ (Clinical research ed.)*, *325*(7361), 430–432. https://doi.org/10.1136/bmj.325.7361.430

Yazbec, A., Borovsky, A., & Kaschak, M. P. (2019). Examining the impact of text style and epistemic beliefs on conceptual change. *PloS one*, *14*(9), e0220766.

Zengilowski, A., Schuetze, B. A., Nash, B. L., & Schallert, D. L. (2020). A critical review of the

  refutation text literature: Methodological confounds, theoretical problems, and possible

  solutions. *Educational Psychologist*, 1-21.

"What would happen if we stopped vaccinations?". Centers for Disease Control and Prevention.

  June 12, 2018.