

Public Perception of Human Applications of CRISPR Gene Editing

An Interactive Qualifying Project to be submitted to the faculty of Worcester Polytechnic Institute in partial fulfilment of the requirements for the Degree of Bachelor of Science



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Abstract

This project's goal was to examine American public opinion and media representation of CRISPR gene editing technology and its human applications. To do so, we analyzed three data sources: public opinion polls, online news articles, and tweets. Our findings show that public perception of CRISPR has been changing over time and the frequency of differently toned content (positive, negative, and neutral) fluctuates. Variation across the three types of sources reveals that American public opinion on CRISPR is not consistent.

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Executive Summary

Introduction

CRISPR, which stands for Clustered Regularly Interspaced Short Palindromic Repeats, is a modern advancement in the field of biotechnology for gene editing, which exploits a cellular defense system in common bacteria. Scientists use this mechanism to cut-and-paste additions to the genome, and even to make pinpoint changes to specific DNA bases, in order to make or correct mutations (Sander & Joung, 2014). However, genetic alteration techniques in general are still in the beginning stages, and there is much speculation regarding the CRISPR procedure and its future uses. The human application of this technology introduces complex morality issues – most of all when modifications on the germline and enhancement procedures are considered.

While the scientific community provides influential opinions that impact the CRISPR gene editing applications, public opinion has also rapidly become one of the influential driving forces behind the limitations and advancements regarding genetic modification and its uses. Specifically, there are opinions that question whether it is our place to change life for what we believe is the better, and that has ultimately become a debate on the legality of the technology applications. Because public opinion can have such a deep impact on the advancements of biotechnology, we examined public opinion polls, news articles, and social media posts in order to provide a more profound analysis of what the American public believes regarding this method of gene therapy and its applications.

Furthermore, special consideration was taken to discover how these opinions change across a variety of demographics, since previous research and literature suggests a wide spectrum of opinions. This spectrum is bounded by two extremes: one side favors continuous research and argues that the value and the possibilities of CRISPR outweigh the risks of its misuse, while the other side argues that it would be irresponsible to use the technology, with all the risks and unknowns currently present, therefore arguing that the risks are greater than the benefits.

Methods

In order to collect representative data of opinion trends across the entire United States that would provide answers to the research questions, we used the following methods: identified and analyzed opinion polls on genetic engineering and CRISPR, used discourse analysis to evaluate online media reports on CRISPR, and mined Twitter for social media activity related to CRISPR.

In order to gauge the potentially wide range of opinions about CRISPR in the United States, we analyzed polls by looking at current snapshots of public opinion within demographics, differently worded polls, and how they may have changed over time. Since CRISPR is a newer technology, there are limited polls and data that specifically focus on CRISPR alone. From the twenty-one polls analyzed, only two explicitly used the term “CRISPR”. For this reason, the terms “gene therapy” and “genetic engineering” were chosen for additional analysis because, while they are broader topics that encompass the same ideas and technologies as the CRISPR method, they have more data and are more publicly recognized through published polls. Different demographics were analyzed within the public opinion polls to get a better sense of each of their corresponding opinions. A study of popular opinion – with a focus on whether the

majority supports or rejects the CRISPR technologies – helped to explain if there are particular preferences corresponding to specific demographics. Looking at polls conducted in different years also displayed varying results since CRISPR technologies are new to the industry and advancing quickly and can reveal the evolution of how and why this correlates with public opinion changes (Blendon, Gorski, & Benson, 2016; CGS, 2014). Differences in results found in preliminary searches also tended to shift due to the wording of questions asked within the polls.

The primary analytical method used to gather quantitative data from our analysis of both the news media and social media discourse were two coding instruments (Appendices A and B) created specifically for the media they would be responsible for parsing. The news media coding instrument was made with a long format, nuanced opinion piece in mind, while the social media discourse coding instrument was tailored towards short, simple statements about CRISPR.

To select news articles for analysis through the news media coding instrument (Appendix A), 6 news sources with different political bias were chosen: two right-leaning, two left-leaning and two centrist sources were selected. The following sources were evaluated: *Fox News*, and *The National Review*, *The New York Times*, *CNN*, *CBS News*, and *USA Today*. All the sources that were chosen are the main, online news sources for significant groups of the U.S. population (Mitchell, et al., 2014). Moreover, every article related to CRISPR’s use in humans, controversy on its uses, and analyses of public opinion polls published from the start of publication to March 2018 were included in this analysis. Keywords present were also counted, including negative terms (“designer babies”, “playing god”, “risk”, “fear”, “eugenics”), and positive terms (“life saving”, “revolutionary”, “less expensive”, “accurate”). We identified these keywords because they suggest either a more favorable or negative approach in the tone.

To select tweets for analysis, we identified five months over the past two years in which major events related to CRISPR occurred: a genetic engineering ethics conference (December 2015); the first use of CRISPR in adults to treat cancer being approved in China (July 2016); the first use of CRISPR on humans in the US (July 2017); the first use of CRISPR on viable human embryos in the US (August 2017); and the release of a video series by CBS entitled “Playing God” (November 2017). We focused on these time periods because we hypothesized that the tone of tweets would differ before and after major events regarding CRISPR. As such, within the months the selected events took place, we coded 25 tweets from immediately before an identified event and 75 tweets from after the event, for a total of 100 tweets per event or 500 tweets total.

Results

Poll Analysis

The results found from analyzing polls can be represented most effectively by separating them into three categories: the evolution of public opinion, public opinion based on poll terminology and language, and public opinion based on demographics.

The evolution of public opinion was found to have changed from high support for inheritable genetic modification, starting at 66% of the poll respondents in favor, to declining support, ending at 41% of the poll respondents in favor, over the span of three decades (CGS Summary of Public Opinion Polls, 2014). Support declined when the genetic modification applications changed to altering physical appearance rather than improving health. The declining trend was similar to the one found in public opinions regarding genetic modification for disease prevention. The support for physical alteration

applications began at 44% in 1986 and progressively decreased to 4% in 2003 (CGS Summary of Public Opinion Polls, 2014).

Overall, there were higher rates of approval in polls that contained questions using positive wording as opposed to using negative wording. The positively worded polls revealed support ranging from 26-87%, while the negatively worded polls only had 11-45% support. The positive and negative language influence in results can also clearly be seen in the questions that referenced somatic therapy applications, which displayed 64% support, while only 39% of people supported somatic enhancement applications (Abed, 2017). Similarly, 65% of people supported germline therapy applications of genetic engineering, but only 26% of people supported heritable germline enhancement (Abed, 2017).

Demographic results were categorized into one of six groups: religious, non-religious, male, female, parents, and non-parental adults. People who were categorized as religious displayed a range of support from 28-50% for genetic engineering applications, while non-religious people had an approval range from 45-75% (Abed, 2017; Potenza, 2017). The male respondent category had a range of support of human genetic modification from 23-63% while the females displayed a range of support from 16-60% for human genetic modification (Napolitano & Ogunseitan, 1999). Parents with a child under the age of 18 displayed 59% approval of the use of genetic engineering to reduce the risk of serious disease, while only 45% of the non-parental adults supported these same uses (Greenwood, 2016). While the absolute percentage of support within a demographic group varied from poll to poll, the difference in the approval rate between two groups of a given demographic appeared remarkably consistent.

Media Discourse Analysis

Data collected from the six different media sources (*Fox News*, *The National Review*, *CBS News*, *USA Today*, *CNN*, and *The New York Times*) reveal that the discourse employed when discussing CRISPR in online news articles shows a similar variation on all bias levels over time, although *The National Review* appears to be an outlier. In addition, we found that events in the scientific community have an effect on the number of published articles, with a peak in media interest whenever a new discovery is made or a trial is approved.

Overall, we found that most articles do not include “CRISPR” in the title (only seven or approximately 7% mention CRISPR in the title), preferring instead to use umbrella terms such as “gene-editing technology”, “gene editing technique”, “gene editing tool”, or simply mentioning the purpose of the study or trial that is being described. Within the articles themselves, 38.7% give a vague or incomplete explanation of CRISPR, 34.7% give a good, if sometimes rudimentary, explanation of what CRISPR does, and the remaining 26.3% do not give an explanation on CRISPR at all.

Furthermore, the analysis concerning the tone of the articles shows a series of trends over time for the presence of positively, negatively, and neutrally toned articles. When scientists started debating the ethical concerns of using CRISPR in human trials in 2015, journalists started to include more negative wording, especially in articles concerning the human germline (embryos and gametes) with a 95.16% correlation between mention of embryos and negative wording in the articles. However, the presentation of multiple opinions on CRISPR in all sources led to the large presence of articles containing both positive and negative words in the form of expositional pieces.

The National Review is an outlier of this trend. This is the only source where most of the articles were written by the same person with a clear bias. The content of the articles was also very different from the other sources. A more “moralistic” approach is employed, giving less importance to whatever new discovery or paper had been published at the time and instead focusing instead on regulation. This was

also the only source that used literary references to science fiction – including references to *Brave New World* and a mention of *The Andromeda Strain*, both of which can be interpreted as negative dystopias related to gene modification.

On the amount of negative versus positive articles separated by political leaning the findings were as follows. Left-leaning sources had a total of 9 (25.71%) positively worded articles, 1 (2.86%) negatively worded articles, 22 (62.86%) articles with positive and negative wording, and 3 (8.57%) with neither. Centrist sources included 1 (4.35%) positive articles, 4 (17.39%) negative articles, 14 (60.87%) with positive and negative wording and 4 (17.39%) with neither. Finally, the right-leaning sources had 13 (35.14%) positive articles (11, 45.83% not including *the National Review*), 11 (29.73%) negative articles (2, 8.33% not including *the National Review*), 12 (32.43%) articles with positive and negative wording (10, 41.67% not including *the National Review*) and 1 (2.70%) with neither (1, 4.17% not including *the National Review*).

Twitter Discourse Analysis

In our analysis of the tone of tweets, we found that 91% of the tweets analyzed were neutral. Additionally, we found that the majority of the tweets about CRISPR from the selected time periods (65%) appeared to be shared directly from news articles, blogs, and scientific journals. We did not find any indication of shifts in tone or content during the selected time periods.

When considering the tone of tweets about CRISPR in the selected time periods, the proportions of positively-, negatively-, and neutrally-toned tweets do change, but only very slightly. The difference between the lowest percentage of neutral tweets, 83% in July of 2017, and the highest percentage of neutral tweets, 95% in July of 2016, August of 2017 and November of 2017 is only 12 tweets (12%). The difference in the highest and lowest percentages of positively-toned tweets are similarly low (from 6% in December 2015 to 0% in July of 2017). In a similar fashion, the difference between the months with the highest and lowest percentages of negatively-toned tweets (10%, 12% in July of 2017 and 2% in July of 2016) are also not significant, given that there were only even 30 tweets (6%) that were negatively intoned.

Discussion

Poll Analysis

From our analysis of polling data, we developed three conclusions. First, public opinion in support of genetic modification techniques followed a decreasing trend over three decades. Second, the poll questions that were phrased using positive syntax and terminology produced higher approval rates than negatively phrased questions. Finally, the demographics of poll respondents also cause differences in the amount of support that genetic engineering receives. Overall, these factors resulted in apparent variation across polling data.

The results found by analyzing the evolution of opinion show that, although there is popular support for genetic engineering, support is slowly decreasing over time. The waning support trend for genetic engineering appears in opinions on both physical changes and disease prevention applications. There is a difference, however, in the amount of support for each application; people are always less supportive of using genetic engineering for physical characteristic improvements than disease prevention.

The public was more receptive and supportive of questions that used positive words, categorized using Table 1. The most support was typically found in regard to applications to improve health, while most of the public did not support the genetic engineering applications for physical characteristic and appearance improvements. Support was limited for applications used for embryos or that would affect future offspring. These could be interpreted to reflect the morality associated with altering or enhancing a living being without their consent, but could also be due to the uncertainty of the resulting effects.

Our analysis of poll results show that certain demographic factors seem to influence the public's opinion on genetic engineering and whether there is support for or rejection of an application. Women are typically less optimistic about the applications than men, and this shows that they are more cautious with their acceptance and support of technologies that have possible risks to humans. The limited acceptance of religious opinions can be interpreted to reflect the morality associated with all religions, meaning that the type of religious affiliation does not matter, but rather it is the degree of religious commitment of the individual that will determine the amount of support they have for genetic engineering.

Media Discourse Analysis

The findings of the analysis made of the six media sources showed results that vary significantly from the hypothesis made at the beginning of this study. First of all, while there are differences in the presentation of CRISPR from sources of different political bias, the breach is not as big as initially thought. Notably, once *The National Review* is separated as an outlier, the number of negative articles in right-leaning sources becomes comparatively smaller to the number of articles with both positive and negative wording and those that are purely positive (becoming the most comparatively positive).

Second, the total number of articles that were analyzed (95, or 20.65% of the original 460) were much smaller than expected once repeated and unrelated pieces were excluded. Considering the number of articles that mentioned CRISPR in passing or as a reference, and the fact that over half of the analyzed articles only vaguely explain what CRISPR is, we can make the inference that the media may have an implied standard on the public's knowledge on the subject. The consistent use of CRISPR as a reference seems even more disconcerting when the fact that it is only rarely mentioned in titles is taken into consideration. Further studies would be necessary to analyze this discrepancy and are out of the scope of this study.

Thirdly, we can make some assumptions on the level of interest the media sources give to the subject based on both the number of articles as well as the investment placed on the articles. While both of the left-leaning sources (*CNN* and *the New York Times*) and the centrist *CBS News* have their own journalists write the published pieces on CRISPR, both *Fox News* and *USA Today* seem to outsource their CRISPR pieces. This can be taken as a sign that less interest and resources go into writing pieces on this topic. The fact that most of the articles from a different source are taken from centrist authors may also explain the number of mixed and positive articles, as well as the smaller number of negative articles.

Twitter Discourse Analysis

In stark contrast to the results of the other analyses, the analysis of the discourse surrounding CRISPR on social media showed that a large proportion of tweets (91%) were neutrally-toned, and that 325 of the 500 total tweets analyzed were simply shared information without the Twitter user's opinion added. Further, there were no trends in the relationship between the time period a tweet was posted (before or after a major event) and the tone of the tweet, as such a large majority was neutral.

Additionally, 78% of all tweets mention CRISPR in the body of the tweet in addition to being tagged with #CRISPR. The percentage of tweets containing CRISPR in the body of the tweet (78%) and the percentage of articles with the word CRISPR in their headline (7.4%) are very different. The percentage of tweets containing neutrally-toned headlines (92% of all tweets analyzed that were article links with headlines included in the tweet) is very different than the percentage of articles analyzed that are neutrally-toned (8.3%, articles containing neither positive nor negative wording). These differences suggest that the distribution of shared articles on Twitter does not reflect representation of the topic in the studied online news sources. In order to have a more comprehensive understanding of American Twitter users' opinions on CRISPR, a further study should be performed to determine what methods American Twitter users employ to find, read, and share articles.

Table of Contents

Abstract	i
Acknowledgements	ii
Executive Summary	iii
Introduction	iii
Methods	iii
Results	iv
Poll Analysis	iv
Media Discourse Analysis	v
Twitter Discourse Analysis	vi
Discussion	vi
Poll Analysis	vi
Media Discourse Analysis	vii
Twitter Discourse Analysis	vii
List of Figures	xi
Introduction	1
Background	2
CRISPR	2
Scientific Community	2
Political Context	3
Public Opinion and Polls	3
The Relevance of Media in Public Opinion	4
Literature Review	5
CRISPR	5
Public Opinion	5
Scientific Opinion	6
Media Reports	7
Social Media	7
Methodology	9
Poll Analysis	9
Discourse Media Analysis	12
Twitter Discourse Analysis	13
	ix

Results	16
Poll Analysis	16
Evolution of Public Opinion	16
Public Opinion Based on Syntax	16
Public Opinion Based on Demographics	19
Discourse Analysis of Media Sources	21
Twitter Discourse Analysis	27
Discussion	32
Poll Analysis	32
Evolution of Public Opinion	32
Public Opinion Based on Syntax	32
Public Opinion Based on Demographics	33
Discourse Analysis of Media	33
Discourse Analysis of Social Media	34
References	36
Appendix A: Coding Instrument for Media Analysis	41
Appendix B: Coding Instrument for Twitter Analysis	44

List of Figures

Fig. 1: Evolution of Public Opinion.....	16
Fig. 2: Public Opinion Based on Syntax.....	17
Fig. 3: Public opinions of polls using negative syntax.....	18
Fig. 4: Public opinions of polls using positive syntax.....	18
Fig. 5: Public opinions based on demographics.....	20
Fig. 6: Approval percentage differences among demographics.....	20
Fig. 7: Number and tone of articles over time.....	23
Fig. 8: Timeline of relevant events and number of articles.....	24
Fig. 9: Tone percentage variations in the right-leaning sources.....	25
Fig. 10: Total article tones by political leaning.....	26
Fig. 11: Tone by political bias.....	27
Fig. 12: Tweet volume by type of engagement.....	28
Fig. 13: Proportion of positive, negative and neutral tweets by selected time period.....	28
Fig. 14: Prevalence of the word CRISPR in Tweets.....	29
Fig. 15: Volume of Tweets by type of link shared.....	29
Fig. 16: Positively, negatively and neutrally tone to tweets by prevalence before events.....	30
Fig. 17: Positively, negatively and neutrally tone to tweets by prevalence after events.....	31

List of Tables

Table 1: Keywords used to separate positive and negative language in the different source.....	11
Table 2: Sources analyzed and their political bias.....	12
Table 3: Time periods selected for Twitter discourse analysis	14

Introduction

The field of genetic modification is constantly changing and advancing to meet the needs presented by our society. Currently, CRISPR gene alteration is one of the most advanced new methods being used and tested by scientists. This particular technique entails targeting specific sequences within the genome and modifying them to change a living organism as desired. These genetic alteration technologies are typically used to change the genes in a way that would correct the advancement of diseases such as cancer, AIDS, Hepatitis B, and a wide variety of genetic disorders. Genetic alteration in general is still in the beginning stages, and, as such, there is much speculation regarding the CRISPR procedure and its future uses.

At the moment, the uncertainty in the future of human genetic modification is due to the limited amount of experiments that have been realized so far; a number that is even smaller when we consider only research done on modification of germline cells (eggs or sperm). Applying these technologies to humans also introduces more complex issues, as different senses of morality and discussions regarding consent affect public opinion. However, the benefits of applying the CRISPR technology to our advancing world could change the way we are affected by genetic mutations that have the ability to cause harm or diseases.

As in other previous cases of emerging biotechnology, public opinion has rapidly become one of the influential driving forces behind the limitations and advancements regarding genetic modification and its uses. Public opinion can have a big impact on regulations and federal funding, as well as on the number of research projects that get funding and thus could allow for a better understanding of the possibilities and limitations of CRISPR. This opinion-driven force has been an influence in limiting advancements, not only regarding gene editing applications with humans, but also for applications such as genetically-engineered crops and reproductive technologies such as *in vitro* fertilization.

Because public opinion can have such a deep impact on the advancements of biotechnology, we investigated public opinion and media representation of CRISPR to provide a more profound analysis on what the public believes this method of gene therapy should be used for. To gain answers, current polls, articles, and social media were analyzed. Furthermore, special consideration was taken to discover how these opinions change across a variety of demographics, since previous research and literature suggests a whole spectrum of opinions, for and against, in all segments of the population. This is marked by two very polarized opposites, with one side more in favor of continuous research and arguing that the value and the possibilities of CRISPR outweigh the risks of its misuse, while the other side argues that it would be irresponsible to use the technology, with all the risks and unknowns currently present, therefore arguing that the risks are greater than the benefits. The end result is the presence of a group of the population that thinks those who oppose the technology are “clutching pearls” and thus preventing people from leading healthier lives, and another group concerned that the scientists are “playing god”, especially when it comes to modifying embryos.

Background

CRISPR

The CRISPR gene editing method is a modern advancement in the field of biotechnology. CRISPR, which stands for Clustered Regularly Interspaced Short Palindromic Repeats is done by exploiting a cellular defense system in common bacteria, where pieces of genetic code are identified and then cut or edited when affected by viruses. This mechanism is used by scientists to cut-and-paste editions to the genome, and even to make pinpoint changes to specific DNA bases, and thus make or correct mutations (Sander & Joung, 2014). The alteration in this method can either be an addition, a removal, or a base change in the DNA sequences (What is CRISPR-Cas9?, 2016). This genetic modification method is different from others because it is more accurate and can target more specific sections of the DNA, making it more cost and time efficient. The increased accuracy of the CRISPR method also decreases the amount of off-target effects within the procedure. The limited off-target effects mean that there are less edits made at unintended locations, which could have otherwise caused new detrimental mutations within the organism. The CRISPR technology permanently alters the genetic code of the organism, which could have otherwise created mutations that could cause disease or death. Although these applications within CRISPR technology seem to have valuable potential for our society, they are still in their beginning stages.

Scientific Community

This fluidity in opinion is not only present in the general public, but background research suggests a great sense of division inside the scientific community as well. Dr. Jennifer Doudna, one of the scientists that worked on the first paper that introduced CRISPR-Cas9 (Jinek et al., 2012), has been adamant in her hopes that this technique should be used within the boundaries of morality. In 2015, Dr. Doudna was part of meetings and contributed to papers on the topic, including the International Summit on Human Gene Editing, which ended with a published summary on steps and precautions moving forward. The summary includes an expressed desire to prevent any work on the human germline so long as we do not know how to avoid the risks of inaccurate editing and the harmful effects that changes of this nature could have on the human population (Committee on Science, Technology, and Law Policy and Global Affairs, 2015). Moreover, the implications of passing the modified genes on to all of the future offspring, especially considering how hard it would be to reverse these changes, the possible uses for enhancement, and the moral and ethical challenges of changing the future of human evolution require careful deliberation (Committee on Science, Technology, And Law Policy And Global Affairs, 2015).

Doudna's publications in *Science* magazine about the considerations to be had going forward have been met with a variety of ongoing responses. Some of these include petitions to include stronger guidelines and ban any research that could potentially lead to changes on the germlines for non-life-threatening reasons, which some scientists argue could lead us back on the path towards eugenics (Pollak, 2015), while others worry that the fear of this potential may hinder the progress in science, which in turn affects a segment of the population who suffers from incurable genetic conditions (Miller, 2015).

Political Context

In the American democratic system, citizens elect representatives to create and implement legislation. People, particularly on the topic of wedge issues, will vote for candidates who represent their views and, in this way, public opinion influences the way representatives vote about legislation surrounding controversial technologies, such as CRISPR research, stem cell research, and even alternative medicines. In the United States, people are currently submitting CRISPR gene therapies under modern methods used to evaluate previous genetic treatments, the CRISPR-Cas9 Germline Editing Therapies (CGETs) are put through “preclinical trials, clinical trials, and post-approval distribution” and before each stage there are “financial and regulatory checkpoints”, which is the method the government uses for ensuring that safe therapies reach the market (Evitt, Mascharak, & Altman, 2015). There are, however, differences of opinion on the subject of using CRISPR in the United States among researchers (Ledford, 2015), and those differences are now forming among bioethicists, the public, and legislators (Baumann, 2016). The scientific community is questioning whether it is our place to change life for what we believe is the better, and that has ultimately become a debate on whether or not one should be allowed to legally.

Public Opinion and Polls

Since this technology is still in its beginning stages of practice, there is much speculation surrounding its uses and applications. The public has a wide range of opinions regarding genetic editing, but the most prevalent are the two opposing poles: either supporting the experiments and applications or opposing the advancements of the technology. Proponents of the gene editing technology approve of advancing the uses to experiment more and ultimately to develop the technology for useful future applications. Opponents reject the gene editing applications and resist the integration of the technologies into society.

Different opinions have corresponding trends within demographics, as seen in United States public polls from the Pew Research Center (Greenwood, 2016). The support or opposition to these technologies is highly conditional and context-driven. For example, though most religious groups do not have a strong corresponding positive or negative opinion regarding gene editing, the atheist demographic strayed from this usual 50/50 split between opinions at either extreme by instead splitting between a 75% approval and a 24% refusal when considering whether they would use gene editing on their baby (Greenwood, 2016). Specific circumstances also play a role in opinions toward the gene editing technology in human embryos. For example, most people, regardless of demographics or religion, would approve of the use of genetic modification in their children if it were a life and death situation. Yet, in regards to the technology in general, the religiously unaffiliated public believed more in the importance of advancing these technologies than in the idea that it is “meddling with nature”, when compared to respondents with a religious affiliation (Greenwood, 2016). Across all reviewed polls, opinions in demographics based in race and ethnicity were, for the most part, evenly split: 50% in support and 50% opposed to genetic editing applications as a whole (Greenwood, 2016). In most of these polls, the opinions tend to shift from strongly supporting the technology in applications with grown adults to strongly opposing the applications regarding embryos and future generations (Begley, 2016; Columbus, 2017; Greenwood, 2016).

The Relevance of Media in Public Opinion

The media also has an impact on the perceptions regarding this area of science. Scientists have long seen the media as the “translator” between new technologies and discoveries to the general public (McCluskey, Kalaitzandonakes, & Swinnen, 2015). As such, the media has the power to spread new notions and validate one position over other, by becoming a platform for a particular idea or agenda for its particular reading demographic. This in no way means that what is published by any particular source is immediately accepted, as other factors such as religious belief, partisan position, age group and direct experience may incline an individual to agree with an article or to rapidly reject it.

In America, 81% of the population has a social media account (Edison Research 2017). This has created a society in which one is able to converse with others without leaving the home and gives others the ability to read and interact with those conversations. Social media is not only used for direct conversations between individuals, but also for individuals to respond to news, public statements, and current events. With such a high percentage of the population using social media platforms, they have become more important and influential in shaping public opinion. For example, Barack Obama’s victory in his 2008 presidential campaign has been attributed in part to the success of Obama’s social media campaign that Republicans at the time were not able replicate (Katz, 2013). In the decade since that election, the importance and relevance of social media to modern American life has only grown. The 2016 election of Donald Trump involved many online campaigns in a similar fashion to the Obama campaign. Rapid dissemination of information directly from the candidates, the tone of Trump and Hillary Clinton’s tweets, and the way that each candidate’s social media followers conversed with each other over Twitter all impacted the election of the President of the United States of America (Yaquib et al., 2017).

The role of social media has expanded to become not only a forum to discuss the news, but a forum from which news is generated, giving these platforms great relevance in the lives of average Americans.

Literature Review

This project required research into a variety of subjects to gain full perspective on the relevant aspects surrounding public opinion of CRISPR. Most of the research was refined to categories based on the technology itself, the analysis of social media data, the analysis of media reports, and public opinion polls. The sources analyzed ranged from scientific journal reports, published articles, national public poll reports, and market reports. From these sources, information was gathered to accomplish the project goal to determine the public opinions on CRISPR and the influences associated with these opinions.

CRISPR

To fully understand the basis of this project, it was imperative to research the technology of CRISPR itself. The CRISPR-Cas9 method includes several steps to target, cut and alter the genomic sequence using crRNAs and the Cas9 enzyme (Questions and Answers about CRISPR, 2017; Sander & Joung, 2014; What is CRISPR-Cas9?, 2016). Although there are other genome editing methods, the CRISPR technology has proved to be more accurate, and more efficient at editing DNA (What is CRISPR-Cas9?, 2016). The research also explained that the CRISPR system has the ability to be customizable and will create great advancements in the biotechnology industry (Questions and Answers about CRISPR, 2017). These sources proved useful in understanding the logistics of the science behind the CRISPR genetic alteration.

Public Opinion

One relevant subject touched upon in this project was the public opinion regarding CRISPR and genetic alteration in general. National public polls put forth through *Statista* contained a variety of topics regarding genetic editing. These polls allowed for research related to specific topics such as knowledge about gene editing, funding for future uses, future applications and how much people would be willing to pay for these new advancements. According to Greenwood (2016), gene editing is a topic that is known to most Americans. Even with this knowledge, there is speculation about how the public feels these technologies should be applied. Jasanoff, Hurlbut, and Saha (2015) explain that, from the scientist perspective, there must be regulations. The way in which the technologies would be regulated could include a variety of officials from different concentrations, such as the scientific and ethical positions, as to represent as much of the public's beliefs as possible (Jasanoff, Hurlbut & Saha, 2015). To determine the public's beliefs on the gene editing applications, Blendon, Gorski & Bendon (2016) had analyzed 17 previous polls. These analytic results reflected that the public opinion shifts from supporting the applications of altering the genes of adults to opposing the technologies when used in embryos (Blendon, Gorski & Bendon, 2016). These negative feelings are also present with the officials present at the global summit, where the criticism was mainly brought by the non-scientific representatives (Begley, 2015). Begley's work is also relevant in the American public opinion that she explains "says no to 'designer babies'", which brings up the issue of the influences and education regarding gene editing technologies (Begley, 2016). According to Eplett, a reason for these differences in support, specifically found in poll results, is due to the language used because language has the ability to alter the perception of the questions asked (Eplett, 2013). More specifically, Ferenstein reveals the results from specific polls that ask the same questions in different wording and produce different results, further reinforcing this idea that language can shift results (Ferenstein, 2015).

Scientific Opinion

There is a variety of opinions within the scientific community, which can be found both in the summary of national and international talks concerning the topic of CRISPR and how scientists should move forward. The Committee on Science, Technology, and Law Policy and Global Affairs determined during the 2015 International Summit on Human Gene Editing that the technology for gene editing was advancing at a rapid pace, with CRISPR being “so overwhelmingly efficient and specific that it is changing our entire outlook for future gene editing”. The same summit also mentions the multiple uses of CRISPR, including learning more about the function of each gene, curing genetic diseases, improving fertilization techniques, and enhancement/selection of traits. The fact that the technology is still in development and that there were still several errors that required fixing before proceeding to more intensive trials and studies was also mentioned, as well as the complicated moral and ethical considerations to be taken regarding gene editing. The presence of very different positions can be seen again here. On one side, there is mention of it being “acceptable when its benefits, both to individuals and to the broader society, exceed its risks, ... though the relevant risks and benefits and levels of acceptable risk are today uncertain” (Harris, 2015). On the other side, there were calls for:

a two-year moratorium on the basic research needed to enable germline human gene editing until an international ban on germline gene editing for reproductive purposes can be secured. [...] The future risks of gene editing are unpredictable [...] which means that the long-term harms may well outweigh the benefits. In addition, researchers and future parents have an obligation to respect the morally relevant status of the human embryo [...] but germline gene editing does not meet this obligation because it either renders the embryo morally neutral or diminishes it to the status of property or goods. (Hacker, 2015)

Furthermore, a concern that the use of these technologies would end up crossing a line while pursuing a noble goal was also mentioned. Some scientists mentioned the possibility of reinforcing existing “economic and social disparities” or reinforce stigma associated with disability. While concerns about eugenics were no longer considered a serious risk, the possibility of racial stigmatization in the use of genetic engineering technologies was also brought up.

A number of articles considering these different positions have been published by *Science* and *Nature*. These include papers written by Jennifer Doudna about the ethical and moral considerations, as well as the possibilities of future research. One such article, written in April 2015, entitled “A prudent path forward for genomic engineering and germline gene modification” was published in *Science*; it called for transparency as science moved forward on CRISPR research, discouraged modifications to the human germline and introduced the idea of creating forums and/or organizations that allowed for scientific and ethical discussions on the topic (Baltimore, et al.). On December 22, 2015, after the International Summit, another article was published in *Nature*. This article, written by Doudna, describes the initial discovery of CRISPR and her growing concerns about the technology being used in unethical ways. An explanation of the results of the Napa Convention, as well as her overall conclusions from the several months she had been working on spreading awareness and calling for conversation are also included, together with a call to scientists to start making more of the conversation and information available to the public.

Responses to the aforementioned articles and to new developments regarding CRISPR are also common. In June 2015, after Chinese scientists attempted to modify human embryos for the first time, Henry I. Miller, who also writes for *The National Review*, wrote an opinion piece arguing against the previous call for a moratorium on this use of CRISPR (mentioned in Baltimore, et al., 2015). His main argument was that, while the technology should be used “sparingly and under scrutiny” it should not be completely limited by a moratorium that would only result in a longer period of time being used to perfect the technique, leaving many of the people who suffer from the effect of genetic conditions, such as sickle anemia and Huntington’s, bound to live with their conditions and their side effects for longer than necessary (Miller, 2015). A completely different point of view is expressed by Robert Pollack in his May 2015 letter to *Science*. The letter mostly focuses on the ability to change the human germline, calling the necessity to “design” the desired “aspects of a child’s inheritance” a modern version of eugenics. He ends the opinion piece by calling the previous recommendation for a moratorium “not enough” to prevent the consequences of designing the genome and asking for a total ban on this use of CRISPR (Pollack, 2015). Another article, written in March 2015, for *Science* discusses the necessity for strict regulation of modification of the human germline, mostly showing concern for the yet unknown possible side effects and unintended mutations of gene modification (Vogel). A secondary concern mentioned is the lack of a good regulatory framework established by the government to regulate the uses and trials of CRISPR.

Media Reports

Different online media sources exist at the moment, and while many small, online-based sources have emerged in the past few years to benefit from the expansion of social media and the ease of sharing information, the most reputable are the ones that have been established for a while. Most of the traditional news sources have over time expanded to include web pages that contain both the articles that are printed in paper copy, as well as some articles that are only available through the internet. Different news sources have been catalogued by the level of bias they have. One of the most common divisions is due to different political leanings – right, left, or center – based on their political commentary, their editorial position, and the bias of the journalist members of the source. This bias can affect the information that is covered, which topics are given more importance, and the general tone and language used to describe a situation, group, or individual (Eberl, Boomgaarden, & Wagner, 2015).

Social Media

Social media, as it integrated itself into the daily life of the American public (Edison Research 2017), has become a powerful research tool due the amount of data that Americans freely give in order to partake in these public forums (Tuten & Mintu-Wimsatt 2018). Private business (Kumar & Choi 2017) and public politicians (Rill & Cardiel 2013), for example, have an interest in both understanding the attitudes and thoughts of the public at large and shaping the attitudes and thoughts of the public to be more positive towards their own preferences. This has created a necessity for qualitative and meaningful analytical techniques and tools that help researchers to understand public discourse now publicly available and saved for posterity (Syrdal & Briggs 2018).

Twitter, as a social media platform, is very useful for conducting research due to the structure of the site (Bruns & Stieglitz 2013), particularly the use of hashtags to denote topics of conversation within tweets. Because topics of conversation are easily searchable, entrepreneurs have been using Twitter to find information on the demands of the consuming public (Motoyama, Goetz & Han 2018) and in much

the same way, researchers are able to use Twitter to gain valuable insight into sentiment (Giachanou & Crestani 2016) using algorithms. Researchers have also used Twitter to gain data on the way that Twitter users interact with each other while discussing particular topics online, how those interactions change over time, and how these interactions may possibly affect life outside of Twitter (Yaqub et al. 2017).

Methodology

In order to collect data that would provide answers to the research questions, we used the following methods: identified and analyzed opinion polls on genetic engineering and CRISPR, used discourse analysis to evaluate media reports on CRISPR, and mined Twitter for data on CRISPR. These methods helped us determine public opinion on the use and advancement of CRISPR technologies because they provided results from a large sample population, which can be representative of opinion trends across the entire United States.

Poll Analysis

In order to gauge the potentially wide range of opinions about CRISPR in the United States, we analyzed public opinion polls. This was done by looking at current snapshots of public opinion within demographics and how they may have changed over time. These opinions and changes could have underlying influences that explain why they relate to certain demographics and times. For this project's purposes, we selected public opinion polls that specifically asked questions about CRISPR technologies in the United States, as well as those that used the terms *gene therapy* and *genetic engineering* (Begley, 2016; Blendon, Gorski, & Benson, 2016; CGS, 2014; Greenwood, 2016; Potenza, 2017). Since CRISPR is a newer technology, there are limited polls and data that specifically focus on CRISPR alone. From the 21 polls analyzed, only 2 explicitly used the term "CRISPR". For this reason, the terms *gene therapy* and *genetic engineering* were chosen for additional analysis because they are broader topics that encompass the same ideas and technologies as the CRISPR method but have more data and are more publicly recognized through published polls.

Different demographics were analyzed within the public opinion polls to get a better sense of each of their corresponding opinions. A study of popular opinion – with a focus on whether the majority supports or rejects the CRISPR technologies – helped to explain if there are particular preferences corresponding to specific demographics. Preliminary searches were done to determine relevant demographics and groups to focus on for this project's purpose of gauging the public's opinion on CRISPR technology uses. These preliminary searches were conducted by searching for polls broken up by demographics, including: gender, religion, and race/ethnicity. The searches revealed that certain demographics had no strong opinion and were equally split between supporting and rejecting genetic engineering in humans, and thus would not produce data that could be used to visualize the potential influences on determining opinion. Race and ethnicity proved to also be irrelevant for this project's purposes since most of polls found in the preliminary searches displayed no specific race or ethnicity displaying a majority opinion leaning toward fully supporting or fully rejecting genetic engineering (Greenwood, 2016). Without a popular opinion between groups, the data would not reveal a correlation between race/ethnicity and opinions about CRISPR technologies and were eliminated from further research. Gender and religion displayed strong popular opinions, either mostly support or mostly reject, regarding genetic engineering technologies. These strong popular opinions could produce data to determine a correlation between gender or religion and genetic engineering opinions (CGS, 2014; Greenwood, 2016; Potenza, 2017). Looking at polls conducted in different years also displayed varying results since CRISPR technologies are new to the industry and advancing quickly and can reveal the evolution of how and why this correlates with public opinion changes (Blendon, Gorski, & Benson, 2016; CGS, 2014).

Differences in results found in preliminary searches also tended to shift due to the wording of questions asked within the polls. Most of the support for genetic engineering was found in polls with terms regarding human health, as opposed to wording regarding improvements to human abilities (Begley, 2016; Potenza, 2017). For example, in the 2017 American Association for the Advancement of Science poll, 59% of people supported the use of gene editing to treat medical conditions or restore health while only 33.2% of people supported the use of gene editing to enhance or improve human abilities (Potenza, 2017). The public was also less receptive to keywords such as "designer babies" or "super humans" (Begley, 2016). These keywords were chosen to describe the correlation between opinion and use of language within the poll since these words most clearly demonstrate the positive and negative connotations through language (Table 1). These keywords are also the most prevalent among polls and other data collection sources such as media and Twitter, which can reinforce the reasoning for the results.

	Terms	Twitter	Polls	Media
Positive	Life saving	X	X	X
	Revolutionary	X		X
	Less expensive	X		X
	Accurate	X		X
	Ground breaking	X		X
	Faster	X		X
	Restore health		X	
	Treat medical diseases	X	X	X
	Therapy	X	X	
Negative	Designer babies	X	X	X
	Playing God	X		X
	Risk	X		X
	Fear	X	X	X
	Problematic	X	X	X
	Controversial	X		X
	Altering Physical Traits		X	
	Superhuman	X	X	
	Enhancement	X	X	
	Embryo Testing	X	X	X

Table 1: Keywords used to separate positive and negative language in the different sources

Discourse Media Analysis

We first analyzed reporting on CRISPR from various online media sources to determine the tone of the articles. This analysis included articles that mention the technology – more specifically articles in which CRISPR is the main topic and the article describes a use (or potential use) in human therapies and/or the ethical and moral implications of said use. A couple of articles that give a review on recent polls on the subject were also analyzed and set apart for comparison.

The media sources were selected from different ideological viewpoints in order to get a more comprehensive view of how each source frames the technology and the possibilities and risks that come from its use. The necessity to have sources with different bias arises from the fact that this bias is what prompts different segments of the population to consider them trustworthy and, as such, use them as their primary sources of information. The level of ideological bias was taken from a 2014 survey by the Pew Research Center (Mitchell, Gottfried, Kiley, & Matsa 2014), which separated media sources by its readers. The sources to be used within each bias segment were chosen due to the high readership that they have among the population of the United States.

Since the entirety of this analysis was constricted to a few weeks, the range of news sources had to be narrowed down to only a few representative ones for each segment. All the sources that were chosen are the main, online news sources for significant groups of the population (Mitchell, et al., 2014). The team evaluated the following sources: *The New York Times*, *CNN*, *CBS News*, *USA Today*, *Fox News*, and *The National Review*. Moreover, every article fitting the above characteristics published since the start of publication and March 2018 was included in this analysis.

Political bias	Left	Center	Right
Source	<i>The New York Times</i> <i>CNN</i>	<i>CBS News</i> <i>USA Today</i>	<i>Fox News</i> <i>The National Review</i>

Table 2: Sources analyzed and their political bias

We tabulated the number of articles from each source and identified the author or original source. Each source’s website is equipped with a search function that is limited by time periods. As it was not always possible to change the date range within the embedded search function, a more detailed search was performed using Google Advanced search. The number of articles was reduced by eliminating those that mention CRISPR only in passing, as well as those that are not related to applications in humans. Then, each article was analyzed to determine whether the article was in favor of, against, or neutral on the use of CRISPR. Keywords present were also counted; this include the following negative terms: “designer babies”, “playing god”, “risk”, “fear”, “eugenics”; and positive terms: “life saving”, “revolutionary”, “less expensive”, “accurate”. These keywords were selected due to their presence in certain types of articles, as they suggest either a more favorable or negative approach in the tone (see Table 1).

The presence of a comparison to science fiction was also noted, as it is usually used by journalists in order to “sensationalize” the topic, get a greater reaction based on “shock value”, thus being able to more easily give the article either positive or negative connotations (Kendal, 2015). Additionally, the tense used to describe potential uses of CRISPR was reviewed. This was done in order to find out how

many articles talk about future possibilities in present tense, and how many give a more realistic view of a technology that is still only in its early stages.

These metrics were combined into a coding instrument (which can be found in Appendix A) – a standardized rubric used to analyze a piece of discourse – that was employed by the group to assign a positive, neutral, or negative tone to each article. While one member of the group performed the analysis on all the sources, ten articles were chosen at random and were given to the two other members of the group to recode in order to compare to the original coding and insure that the coding instrument was efficient for this study. Once the efficacy of the coding instrument was proved to be high, all of the articles found on the media sources that fulfilled the aforementioned requirements were coded. All of this analysis allowed for a better understanding of the stances of each media source, and the data we gather will be compared to the number on the polls and the discourse analysis of Twitter.

Twitter Discourse Analysis

In order to determine the nature of the discourse on CRISPR on social media in the United States, we used a coding instrument, to analyze content on Twitter. Twitter was chosen as the subject of this analysis because Twitter is a popular social media platform in the US, with 68 million active users in the country (Twitter, 2018), 74% of whom use Twitter as their primary source of news (Bialik & Matsa, 2017).

The coding instrument (Appendix B) is primarily focused on the categorization of tweets by language, type of engagement, and date and time posted to allow for analysis of the types of tweets that are written concerning important moments in CRISPR's history. The coding instrument reveals if the author of a tweet used positive or negative words about CRISPR, what type of category the tweet is (Lovejoy & Saxton, 2012), and what the topic of the tweet is. From research, it was found there are generally three types of social media posts, Informational, Community, and Action, based on providing people information, engaging the community, and attempting to convince the community to take physical action. Because Twitter was chosen as our social media platform to analyze, several other categories of tweets, such as opinions (tweets solely containing an opinions), broadcasts (tweets solely containing a link to other content with no input from the user who shares the link), and inquisitive tweets (tweets addressed to a person or community used to gain information) were added. Because of the conversational tone of Twitter, the coding instrument had to allow for categorization if a tweet was simply an opinion, a link to another page with no additional input given, or a tweet meant to gather information from a specific person or specific group of people. These categories allow results from the coding instrument to be used to compare the tone and type of tweets from different specific time periods. When searching for tweets to use for this analysis, tweets from time periods before and after important events within CRISPR's research history were selected. These tweets were also filtered to only include tweets from the geographic area of the United States, and from those, only tweets in English.

The coding instrument begins with three basic questions, asking if the tweet: 1) uses the term "CRISPR," 2) uses positive words to describe CRISPR, and 3) uses negative words to describe CRISPR. The next three questions relate to categorizing the tweet. Lovejoy and Saxton's (2012) three categories of tweets were used as categories of tweet, but in addition to informational, community, and action tweets, tweets could also be opinion based, a simple broadcasted message with no additional thoughts, or an inquisitive tweet. This data was collected in order to determine how users who discussed CRISPR were engaging with Twitter. It is then considered whether the tweet is a response to another tweet, and the

category of that tweet, and then the topic of the tweet is recorded. Because of the potential for conversations on Twitter as a platform, understanding which and how many tweets are responses are important for characterizing the discourse on Twitter. The topic of the tweet was recorded in order to gather data on what people were discussing relating to CRISPR, and to be able to find if there were patterns shared between tweets on the same subject. Finally, the type of link within the tweet, should the tweet have a link, is recorded, along with the URL of the tweet and the date it was published. These allow for the cataloging of tweets within a database, as well as determining the sources that users of Twitter were drawing upon.

Due to the time constraints and the labor required in using a manual coding instrument, it was not possible to code every tweet posted around the time of a notable event. We therefore chose to randomly select a limited number of tweets before and after notable events or major announcements on CRISPR. For each time period selected, twenty-five tweets were taken from before the referenced event, and seventy-five after, to allow for a comparative analysis. These time periods include: December 2015, when Jennifer Doudna and several other genetic engineering researchers met to discuss a potential ban on editing heritable genes in humans using CRISPR (Doudna, 2015); July 2016, when Chinese scientists gained approval to test CRISPR derived treatments on adult patients with aggressive lung cancer (Cyranski, 2016); July 2017, when scientists in the US edited a human embryo using CRISPR (Howard, 2017); August 2017, when CRISPR was again used to alter viable human embryos (Ledford, 2017); and November 2017, after CBS released a series of videos and articles entitled “Playing God” (CBS, 2017). This selective sampling allowed us to analyze discussions on CRISPR over time and how the discussions differ from the news articles published at the time by comparing results from coded news articles and coded tweets from the selected time period.

Announcement	Date	Citation
Genetic Engineering Ethics Conference	December 2015	(Doudna, 2015)
First Trials of CRISPR Therapy Developed for Adults	July 2016	(Cyranski, 2016)
First Embryo Edited by United States CRISPR Researchers	July 2017	(Howard, 2017)
Viable Human Embryo Altered in the United States Using CRISPR	August 2017	(Ledford, 2017)
CBS Releases “Playing God”	November, 2017	(CBS, 2017)

Table 3: Time Periods Selected for Twitter Discourse Analysis

There are, however, inherent issues with using Twitter as a data source. There is very little demographic data associated with tweets (other than the location of a tweet being stored in the tweet as data), and there is no real way to determine which users are bots and which users are people (Sloan, et al., 2013). Fortunately, Twitter's advanced search options allow for users to filter search results by geographic location. This allowed for a sample population of tweets for analysis that have been confirmed to be from within the United States.

Results

Poll Analysis

The results found from analyzing polls can be represented most effectively by separating them into three categories: the evolution of public opinion, public opinion based on poll terminology and language, and public opinion based on demographics.

Evolution of Public Opinion

The evolution of public opinion was found to have changed from high support of inheritable genetic modification to decreased support over the span of three decades. As seen in Figure 1, the public had high support in regard to the use of genetic modification for applications related to disease prevention, starting at 66% in 1992 (CGS Summary of Public Opinion Polls, 2014). This support increased slightly to 72% in 1996, but progressively decreased to 41% by 2003 (CGS Summary of Public Opinion Polls, 2014). Support was lower when the genetic modification applications changed from altering physical appearance rather than health applications, but followed a similar trend as the opinions about disease prevention. The support began at 44% in 1986 and progressively decreased to 4% in 2003 (CGS Summary of Public Opinion Polls, 2014). The difference between the disease prevention and physical trait change opinions is that the support for physical trait changes increased again to 16% in 2014 (CGS Summary of Public Opinion Polls, 2014).

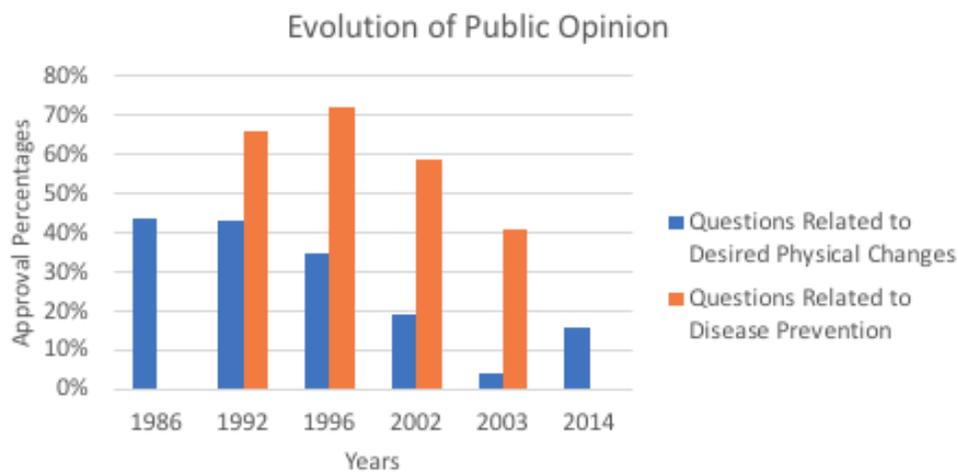


Figure 1: The graph displays the percentage of the public that supported inheritable genetic engineering based on similar poll questions asked over a time period from 1986 to 2014.

Public Opinion Based on Syntax

Overall, there were higher rates of approval in polls that contained questions using positive wording as opposed to using negative wording. The categorization of wording was based on Table 1. The topics within polls that had been worded in both positively and negative language are displayed in Figure

2. The positively worded polls, as seen in Figures 2 and 3, gained support ranging from 26-87%, while the negatively worded polls, displayed in Figures 2 and 4, only had 11-45% support. Specific differences can be seen in the results from the polls referencing gene editing techniques being applied to “treat medical conditions or restore health” that had 60% of people’s support, while only 30% of people supported the applications “to enhance or improve human abilities” (Potenza, 2017). Questions related to “improving intelligence” only received 44% of support (Blendon, Gorski, & Benson, 2016) and questions related to “improving physical characteristics” of embryos received the lowest support of 11% (Bedgley, 2016; King, 2016). Similarly, it was found that there were high levels of support in questions related to “improving health” and “curing fatal disease”, which had 65% and 87% of the public’s support, respectively. Language that referenced the genetic alteration of embryos received low support overall, but received a higher percentage of support when the applications were in reference to disease risk reduction. The support was at 45% for the questions that mentioned the necessity of testing on human embryos (Greenwood, 2016), 44% of the public approved the funding of research in genetic engineering before birth to reduce disease risk (King, 2016), and only 26% supported gene alteration of embryos to reduce risks of disease (Begley, 2016). The positive and negative language influence in results can also clearly be seen in the questions that referenced somatic therapy applications that gained 64% support, while only 39% of people supported somatic enhancement applications (Abed, 2017). Similarly, 65% of people supported germline therapy applications of genetic engineering but only 26% of people supported heritable germline enhancement (Abed, 2017).

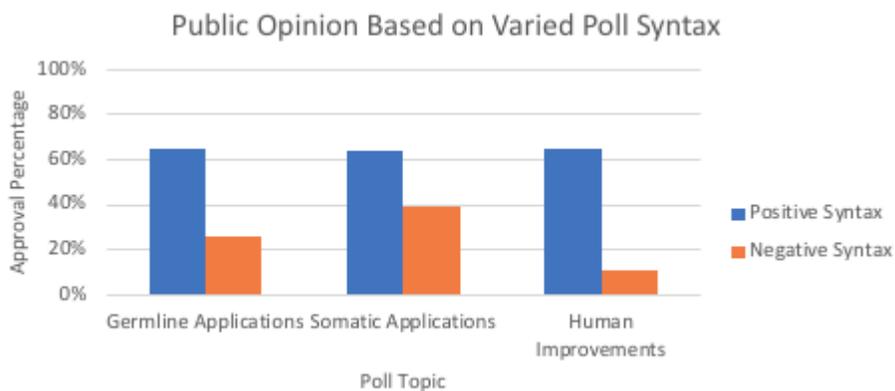


Figure 2: The graph displays the percentage of the public that supported the same themed questions asked in both positive and negative terminology, based on Table 1.

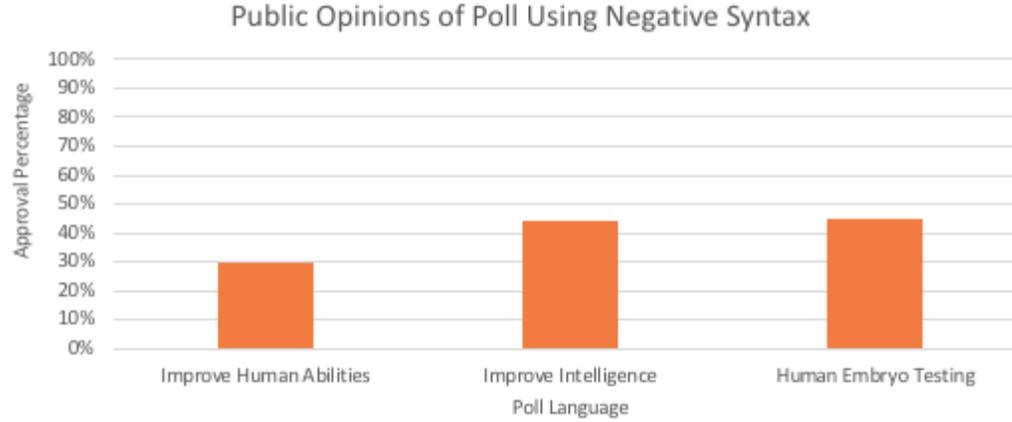


Figure 3: The graph displays the percentage of the public that supported genetic engineering when asked questions using negative terminology, based on Table 1.

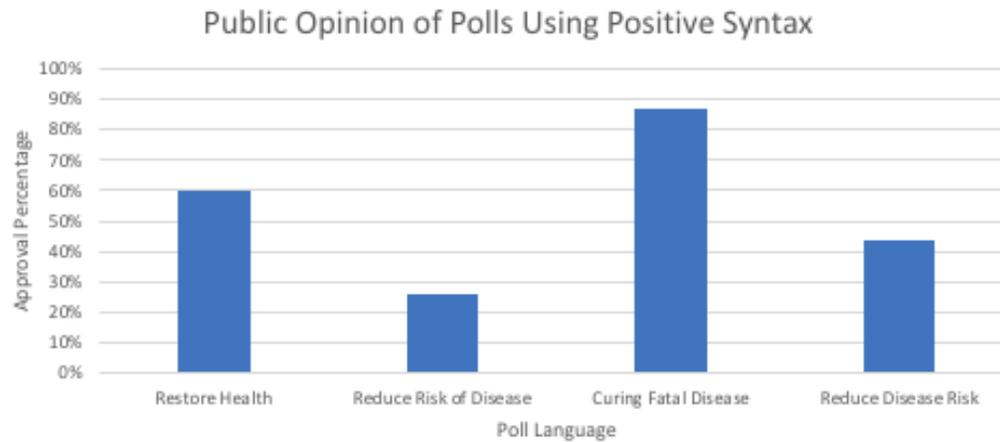


Figure 4: The graph displays the percentage of the public that supported genetic engineering when asked questions using positive terminology, based on Table 1.

Public Opinion Based on Demographics

The results for the opinions related to certain demographics were categorized into one of six groups. The groups, or demographics, included were people who were either religious, non-religious, male, female, parents, or non-parental adults. A range of support was displayed within individual demographics due to multiple different questions asked in polls, resulting in varying responses. These resulting support ranges are displayed in Figure 5, with separate questions within similar demographics displayed as dots along the same vertical axis. People who were categorized as religious displayed 28% support for genetic engineering enhancement applications as well as 50% support for applications in health restoration (Abed, 2017; Potenza, 2017). Non-religious people had an approval range from 45-75%. The non-religious respondents showed 45% support in applications to enhance human characteristics, while 75% supported genetic engineering applications for health reasons (Abed, 2017; Potenza, 2017). The male respondent category had a range of support from 23-63%. The 23% support was found in questions related to germ-line therapy uses of gene editing, while the 63% of support was found in a general and vague question asking if they supported genetic engineering as a whole (Napolitano & Ogunseitani, 1999). Another question revealed that 58% of males support gene therapy in somatic cell applications (Napolitano & Ogunseitani, 1999). The female respondents had lower support for gene editing, which ranged from 16-60%. The question related to germ-line therapy also had the lowest support at 16% for females (Napolitano & Ogunseitani, 1999). The female support increased to 46% for the general question about supporting genetic engineering applications as a whole (Napolitano & Ogunseitani, 1999). The highest female support of 60% was found in the question asking about gene therapy in somatic cells (Napolitano & Ogunseitani, 1999). The final two categories of respondents were parents and non-parental adults. The parents with a child under the age of 18 displayed 59% approval of the use of genetic engineering to reduce the risk of serious disease, while only 45% of the non-parental adults supported these same uses (Greenwood, 2016).

While the absolute percentage of support within a demographic group varied from poll to poll, the difference in the approval rate between two groups of a given demographic appeared remarkably consistent. As seen in Figure 6, there are significant differences between the approval rates within groups in the same demographic. For example, among all three polls shown in Figure 5, the absolute amount of approval varied widely among the polls, from 23-63% approval for males and 16-60% approval for females. However, the difference between the approval rate for males and females was highly similar in all three polls, with about 7% more approval by men than women in all three polls (Figure 6). A similar phenomenon was noted for approval ratings between religious and non-religious people, with non-religious persons reporting about 21% greater approval than religious persons.

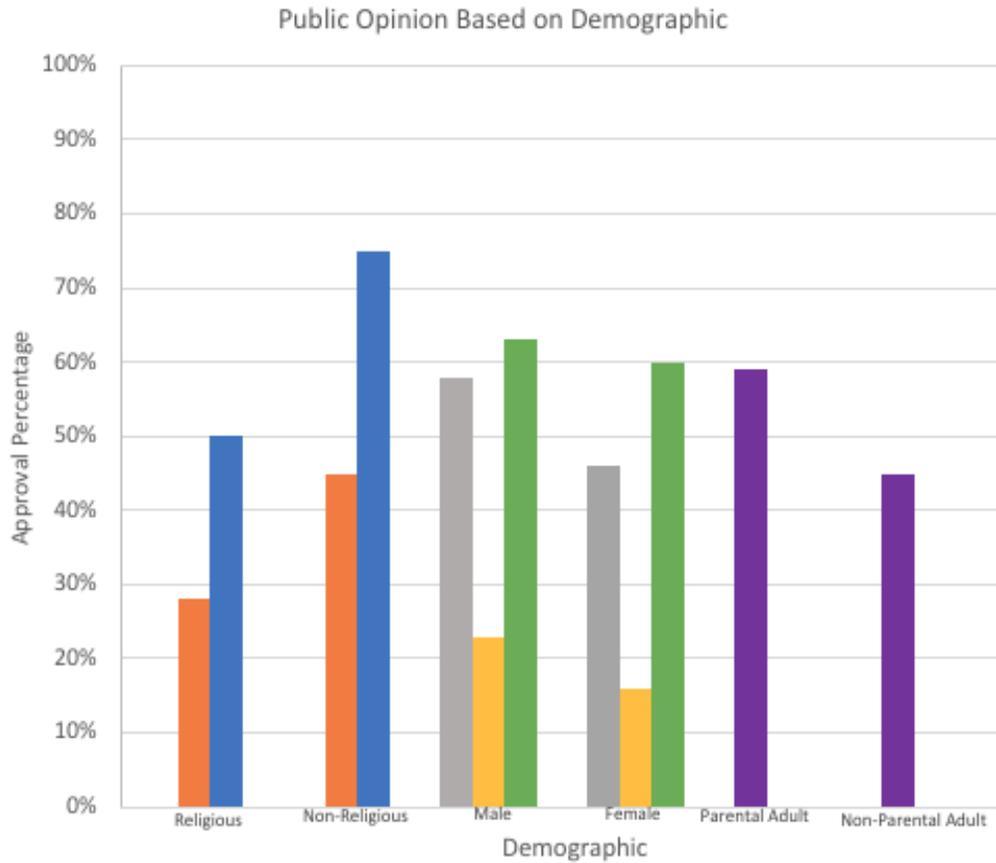


Figure 5: The graph displays the percentage of the public that supported any genetic engineering applications based on their corresponding demographics. Similar bar colors signify corresponding questions asked among demographic groups.

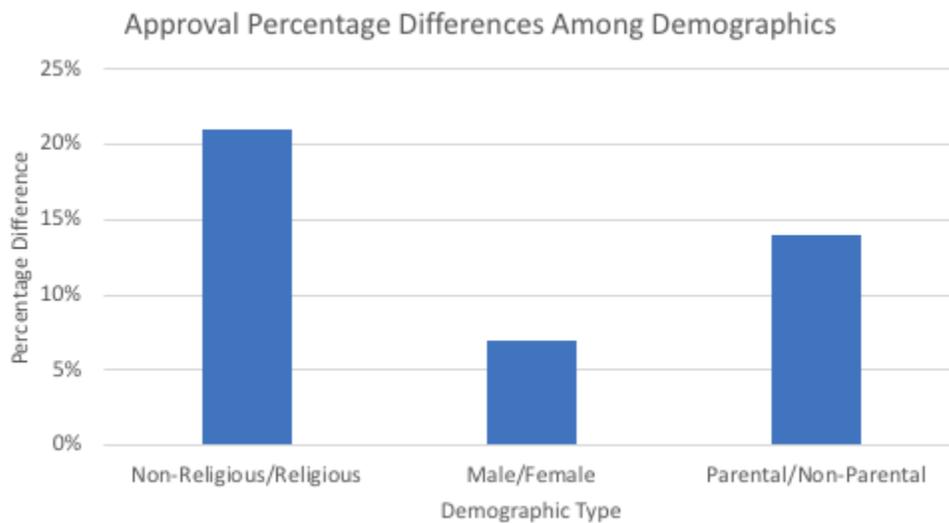


Figure 6: The graph displays the approval percentage differences between similar demographic groups when asked the same questions.

Discourse Analysis of Media Sources

The results from the data collected on the six different media sources (*Fox News*, *The National Review*, *CBS News*, *USA Today*, *CNN*, and *The New York Times*) reveal the overall evolution of the discourse employed when discussing CRISPR. Trends over time show a similar variation on all bias levels, with *The National Review* being an outlier, as will be explained in the following paragraphs. Certain differences can be found between the writing of articles that come from different sources, but the general trend is maintained. The effect of events in the scientific community globally can be seen in Figure 7, where the number of total articles from the aforementioned sources is shown in comparison with events occurring. The graph clearly shows an increase whenever a major breakthrough or international event occurs. Two particular events caused the most reaction from the media, in number of articles: the International Summit on Gene Editing conference in December 2015 (National Academy of Sciences, Engineering, and Medicine, 2015), and the first viable embryo modification trial in the United States in July 2017 (Servick, 2017).

First, most articles do not include “CRISPR” in the title, preferring instead to use umbrella terms such as “gene-editing technology”, “gene editing technique”, “gene editing tool” or simply mentioning the purpose of the study or trial that is being described. From the total pool of ninety-five articles, only seven (~7%) mention CRISPR in the title; all the others use an umbrella term such as the ones mentioned above or mention a possible future use of CRISPR. These can be exemplified by the following titles: “In U.S first, scientists edit genes of human embryos” (*The Associated Press*, 2017), “Gene Therapy for Cancer: Overregulation Will Delay Its Benefits to Patients” (*The National Review*, 2016), “China gets into the genetic breakthrough business” (*CNN*, 2016), “A Powerful New Way to Edit DNA” (*The New York Times*, 2014), “DNA breakthrough: Scientists repair genes in human embryos to prevent inherited diseases” (*Fox News*, 2017), “Cure for HIV reportedly 3 years away” (*Fox News*, 2016). Within the articles themselves, 38.7% give a vague or incomplete explanation of CRISPR, 34.7% give a good, if sometimes rudimentary, explanation of what CRISPR does and the rest (26.3%) do not give an explanation on CRISPR at all.

Next, the analysis concerning the tone of the articles shows a series of trends over time for the presence of positive, negative and of neutral articles. The selected sources that were analyzed present a total of three articles (two by *Fox News* and one by *The New York Times*) on CRISPR during the first two years after the discovery was made. Of these early publications on CRISPR, written between 2013 and 2014, both of the ones written by *Fox News* were hopeful and positive, lauding the technique as a technological advancement that could be the key to solve hereditary conditions and cure diseases such as cancer and HIV. The article by *The New York Times* includes both praise for the potential of the technology, as well as some negative commentary about the possible misuse of the technology in the future. The overall tone of the articles in time, since 2015, can be observed in Figure 8, where all articles reviewed are considered and the number of articles that include positive, negative, both or neither language are represented graphically over time.

When scientists started debating the ethical concerns of using CRISPR in human trials in 2015, the articles started including more negative wording, especially those concerning the human germline (embryos and gametes) with a 95.16% correlation between mention of embryos and negative wording in the articles. In the midst of these mostly negative articles, there were twenty-five fully positive articles, mostly concerning the use of CRISPR to cure diseases in adults. The mixed positions in all sources have led to the presence of articles containing both positive and negative words in the form of expositional pieces. The structure of these reports is the following: the subject is presented, scientific opinion is shown

to be mostly supportive, followed by a discussion on the ethical implications of using gene editing technologies to make changes in the human genome versus the possible benefits that could come with the use of the technology.

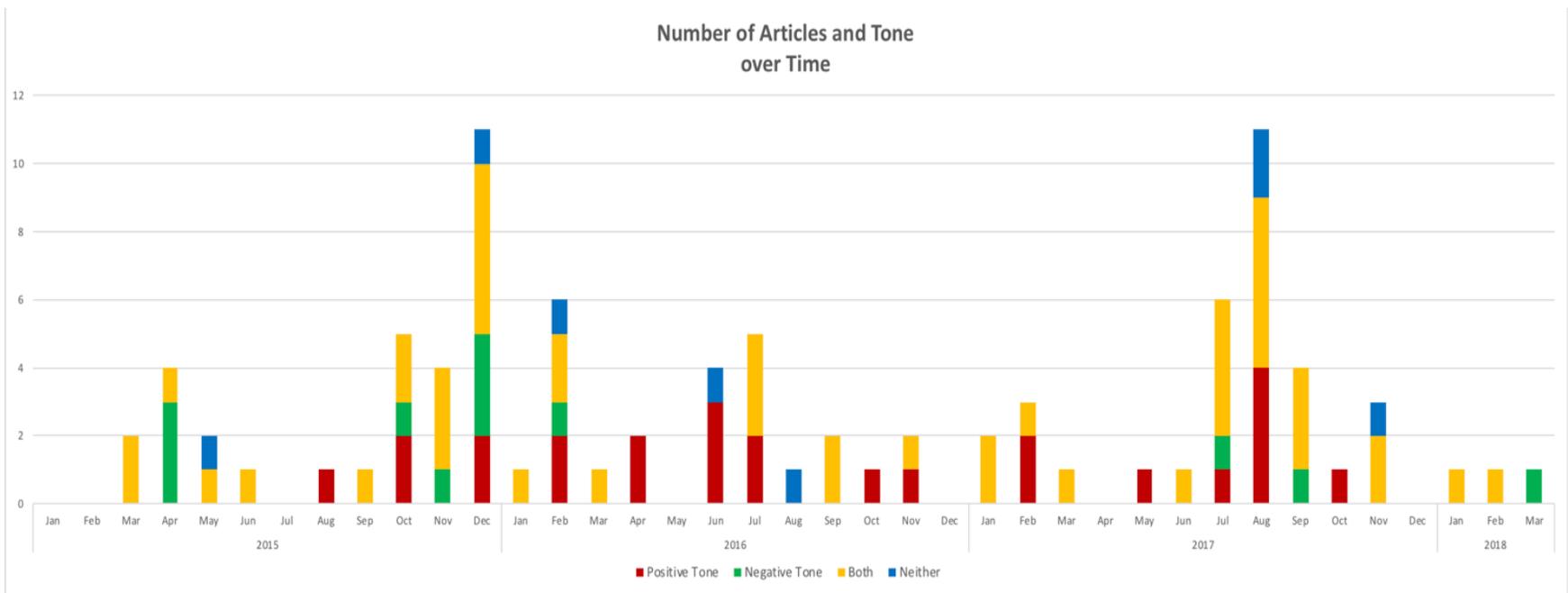


Figure 7: Trend of tone in articles about CRISPR, from all 6 sources, since 2015 until March 2018.

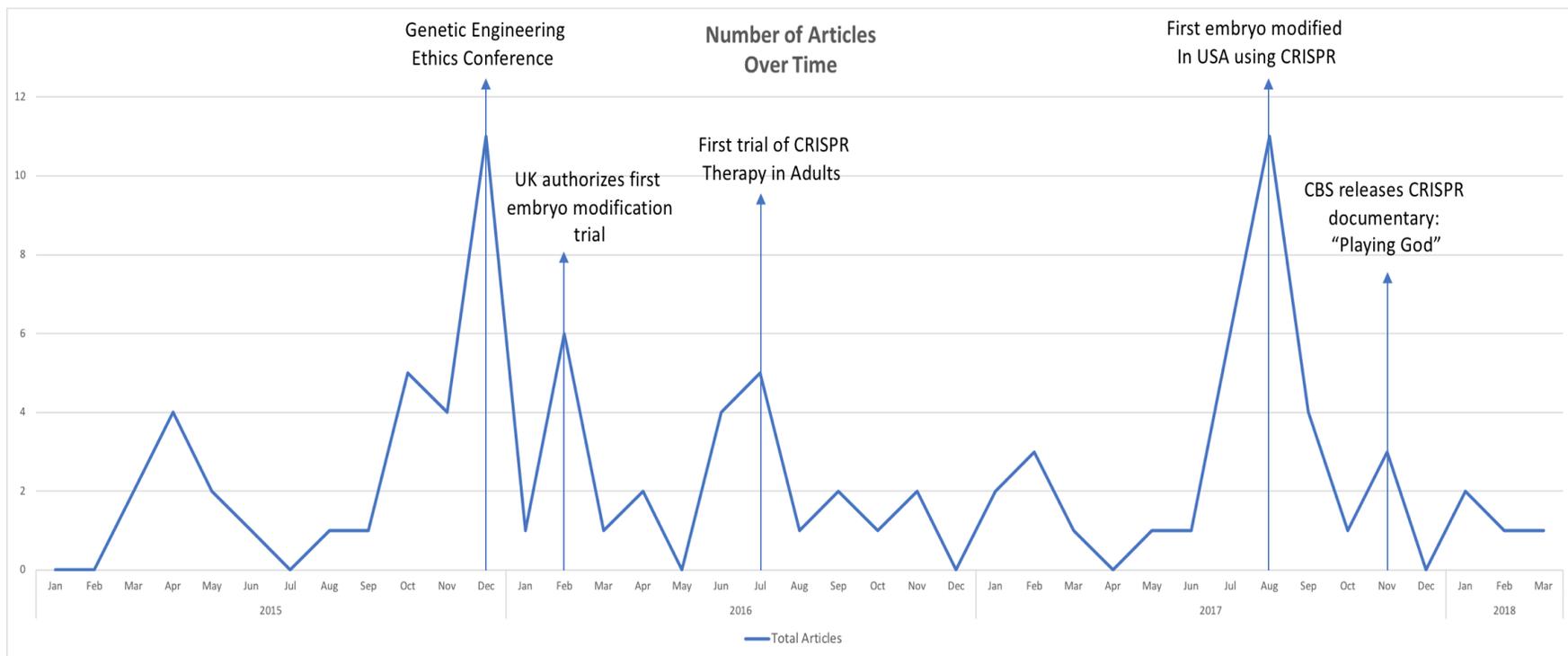


Figure 8: Number of total articles over time and important events regarding CRISPR use in humans.

The National Review is an outlier of this trend. Its major contributor for science articles, Wesley J. Smith, is in opposition to any kind of genetic engineering. Of the thirteen articles that were analyzed from *The National Review*, ten (76.9%) of the articles were written by Smith. Henry I. Miller, a less frequent contributor, has a slightly positive leaning on the subject, at least concerning its use to benefit adults suffering from cancer and similar diseases. This is the only source where most of the articles were written by the same person with a clear bias. The content of the articles was also very different from the other sources. Most of the articles contained some quotes from studies or journals as well as commentary about those quotes. A more “moralistic” approach is given, giving less importance to whatever new discovery or paper had been published at the time, focusing instead on regulation and criticizing the scientists who would proceed with research in the area and the politicians who allow said research. This was also the only source that used literary references to science fiction. Four of the total articles written include a reference to *Brave New World*, and one of these also included a mention of *The Andromeda Strain* both of which can be interpreted as negative dystopias related to gene modification. The particular effect of this source can be easily distinguished in Figure 9 below. The number of negative articles increases dramatically when the data from *The National Review* are considered.

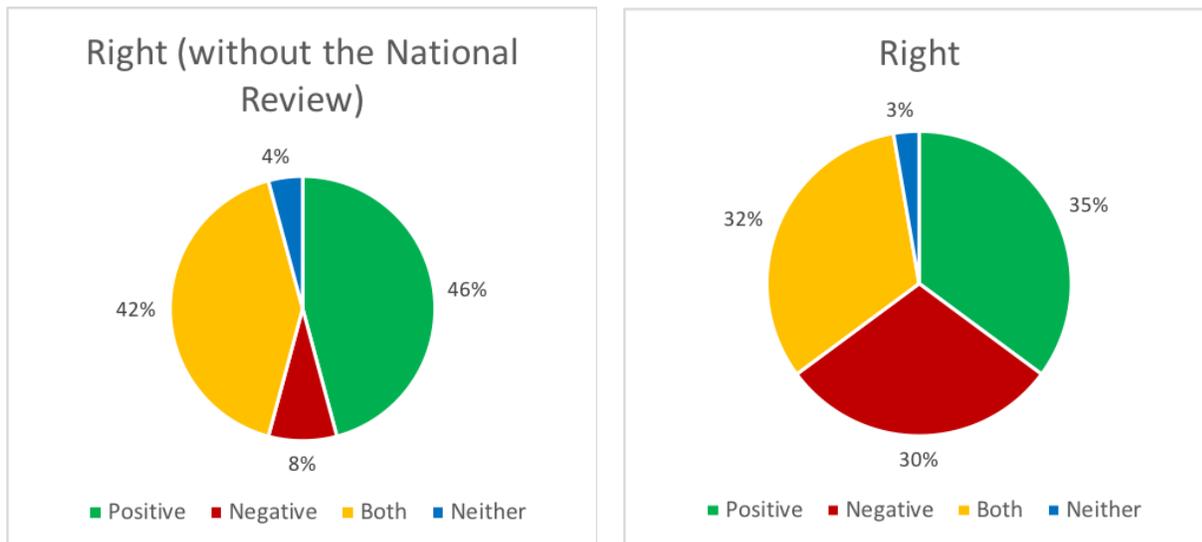


Figure 9: Article tones in Right-leaning news sources with and without considering *The National Review*. Shows the differences the outlier makes in the total trend.

Both left-leaning sources (*The New York Times* and *CNN*) have their articles written by members of their journalistic group. All fourteen articles from *CNN* were written by one of their reporters, and twenty out of twenty-one articles from *The New York Times* written by one of their reporters (except for one that was credited as being taken from the *Associated Press*). This is also the case for the center source *CBS news*, which claimed most of the articles (13 out of 14 total) as their own, four (28.5%) credited as being in conjunction with the *Associated Press*, and one article credited to *Livescience.com*. *USA Today* claimed five of their articles as theirs, with one of them credited as a work in conjunction with *The Guardian*. The other articles were credited to *The Motley Fool*, *The Wilmington, Delaware News Journal* and *The Independent*. On the right-leaning side, *Fox News* only claimed nine (36%) of their articles were written by journalist members of their staff. The others were written by *the Associated Press* (five articles, 10%), *Reuters* (six articles, 24%), *Stat* (two articles, 8%), *Digital Trends* (one article, 4%) and *Newser*

(two articles, 8%). Finally, *The National Review* claimed 100% of their thirteen articles were written by a member of their staff. It must be noted that both *Fox News* and *CBS News* just claimed articles by labeling them with their name, and no author was actually credited for most of the pieces (only four pieces credited to an author by *CBS News* and five by *Fox News*).

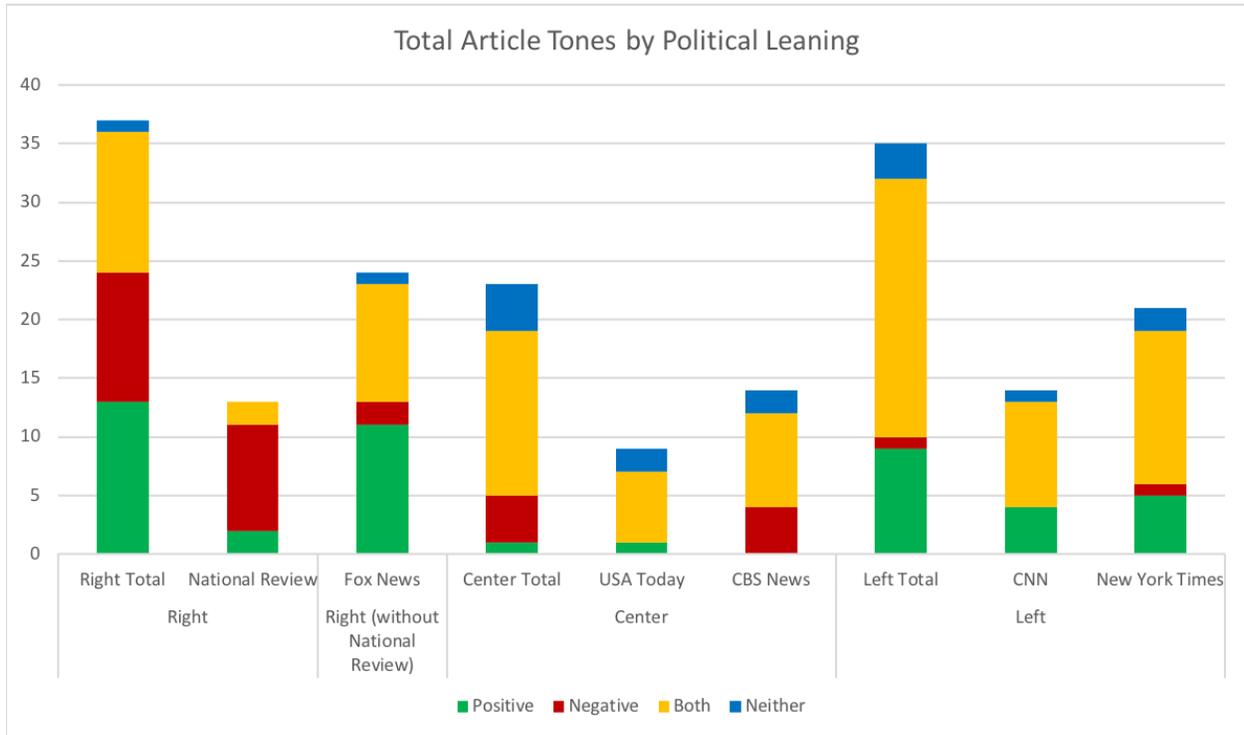


Figure 10: Leaning of articles separated by political leaning of the source

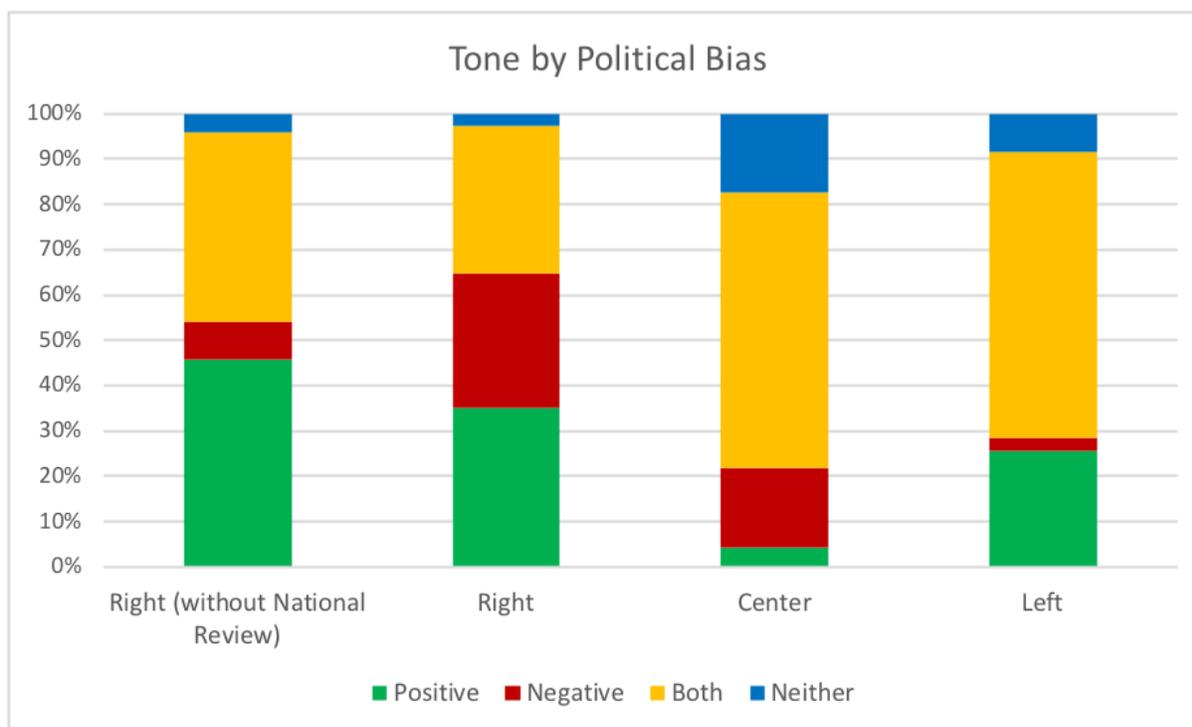


Figure 11: Total percentage of the tone of the articles separated by political leaning of the source.

On the amount of negative versus positive articles written by each source (which can be seen in Figure 10 and Figure 11), *The National Review* has a total of fourteen negative articles and two positive articles. *Fox News* has two negative articles, ten positive articles, two slightly positive articles, and ten articles where both negative and positive wording was used to describe CRISPR. *USA Today* has zero articles with just negative wording, two articles with positive wording only, six articles that used both positive and negative terms for CRISPR as well as two articles where neither positive nor negative wording was used. *CBS News* had zero negative articles, four positive articles, eight articles with both positive and negative wording and two articles with neither positive nor negative wording. *The New York Times* has a total of two negative articles, five positive articles, thirteen neutral articles and one article that include neither positive nor negative wording. Finally, *CNN* has a total of zero negative articles, three positive articles, nine neutral articles and one article that include neither positive nor negative wording.

Twitter Discourse Analysis

The results from the analysis of Twitter discourse reveal how some American users of Twitter have used the platform to discuss CRISPR. We found that across the selected months studied, only the topics of conversation changed. The majority of the tweets discussing CRISPR on Twitter (65%, from our analysis, Figure 12) were categorized as “broadcast” and contained links to news articles, blogs, academic journals, and videos, 299 of which (92%) contain no positive or negative wording (Figure 13).

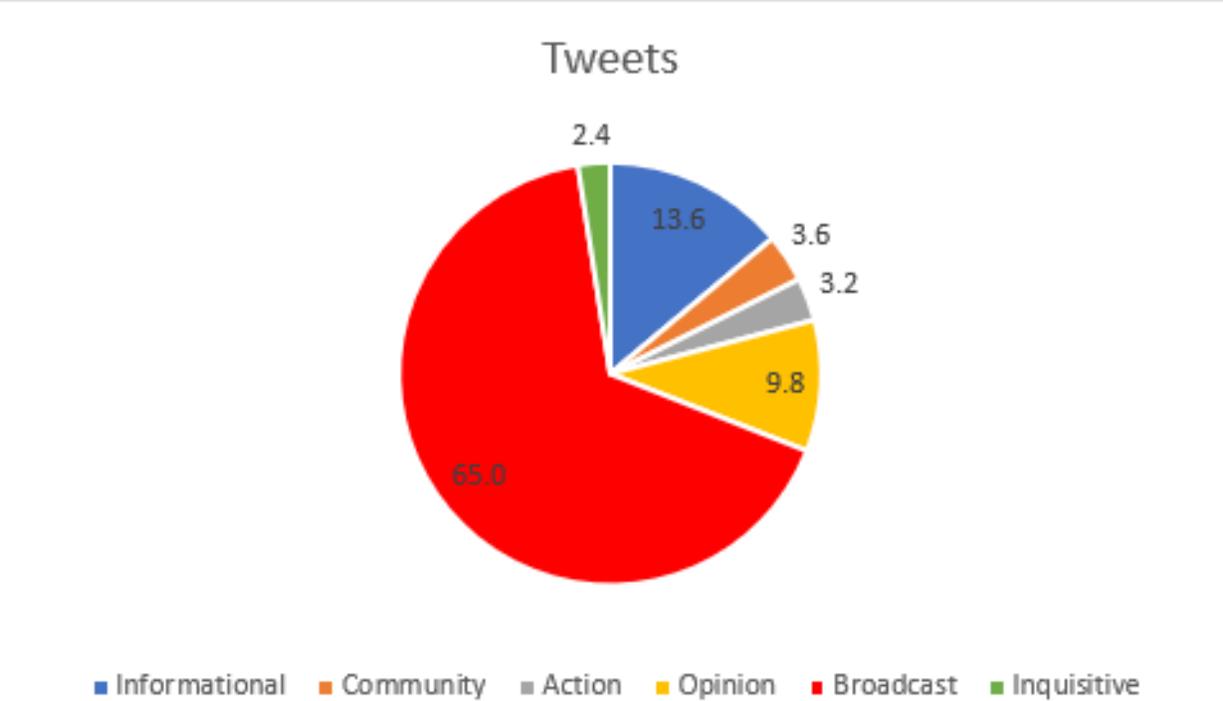


Figure 12. Tweet Volume by Type of Engagement

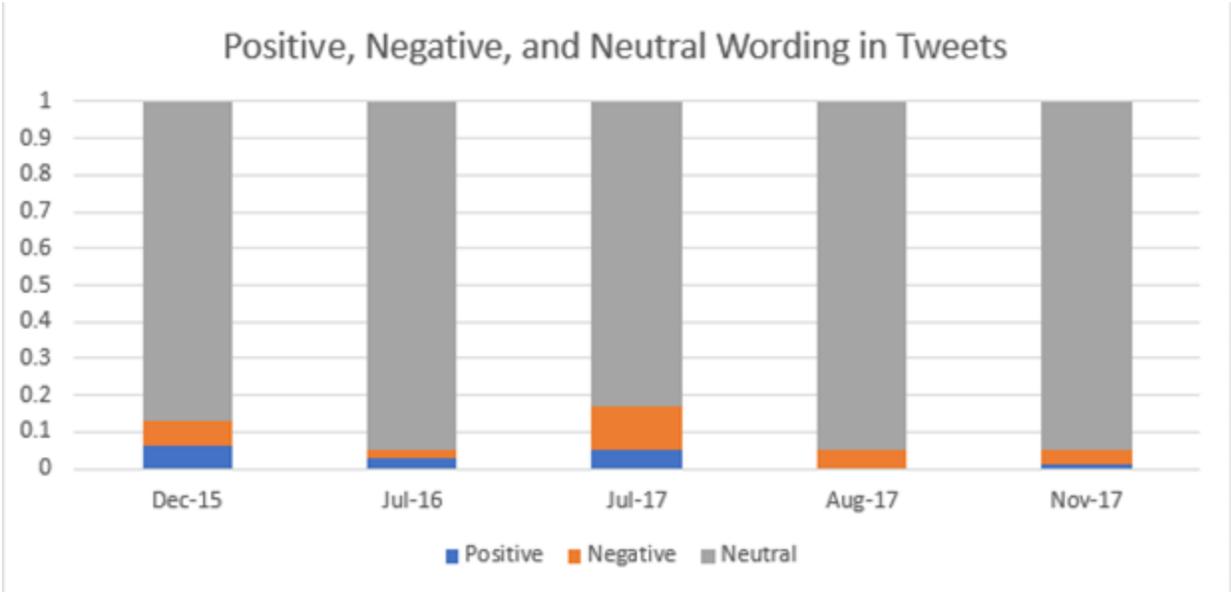


Figure 13: Proportion of Positive, Negative, and Neutral Tweets by Selected Time Period

As seen in Figure 10, broadcasts, the category typified as direct links to other content without comment are the most common tweets about CRISPR by a wide margin. The vast majority of tweets, 455 out of the 500 surveyed (91%) were neutrally-worded (Figure 13).

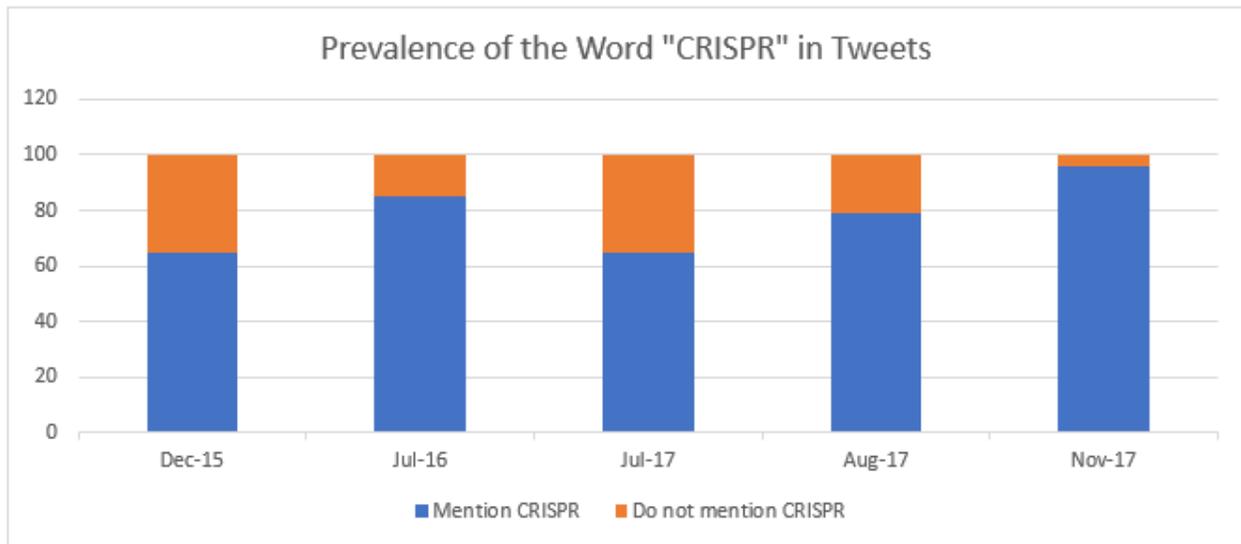


Figure 14: Prevalence of the Word “CRISPR” in Tweets

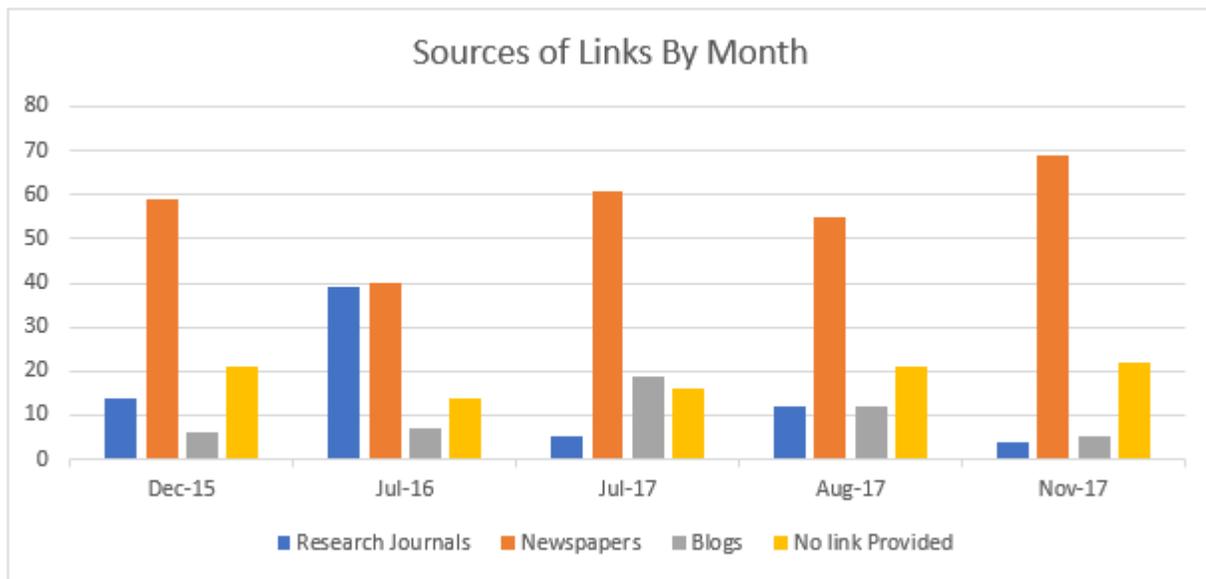


Figure 15: Volume of Tweets by Type of Link by Selected Time Period

As seen in Figure 15, the majority of tweets analyzed (390/500, 78%) mention CRISPR by name in the body of the tweet, although CRISPR was present as a hashtag in every tweet analyzed. When analyzed in the context of the results of our media discourse analysis, it appears unusual that the majority of tweets analyzed (65%) simply linked to a source about CRISPR without additional comment, as only 7.4% of identified news stories contained the term CRISPR in the title. Additionally, in Figure 15, newspapers are always the most shared form of link (284 out of the 500 tweets total), and only in July of 2016 did Twitter users start linking to any other source of media in significant quantities (39 tweets linked to academic journals, compared to the 40 tweets that linked to newspaper articles). The 284 tweets with

links to newspaper articles vastly outnumbered the second most likely type of tweet – ones that contained no link at all (94 tweets).

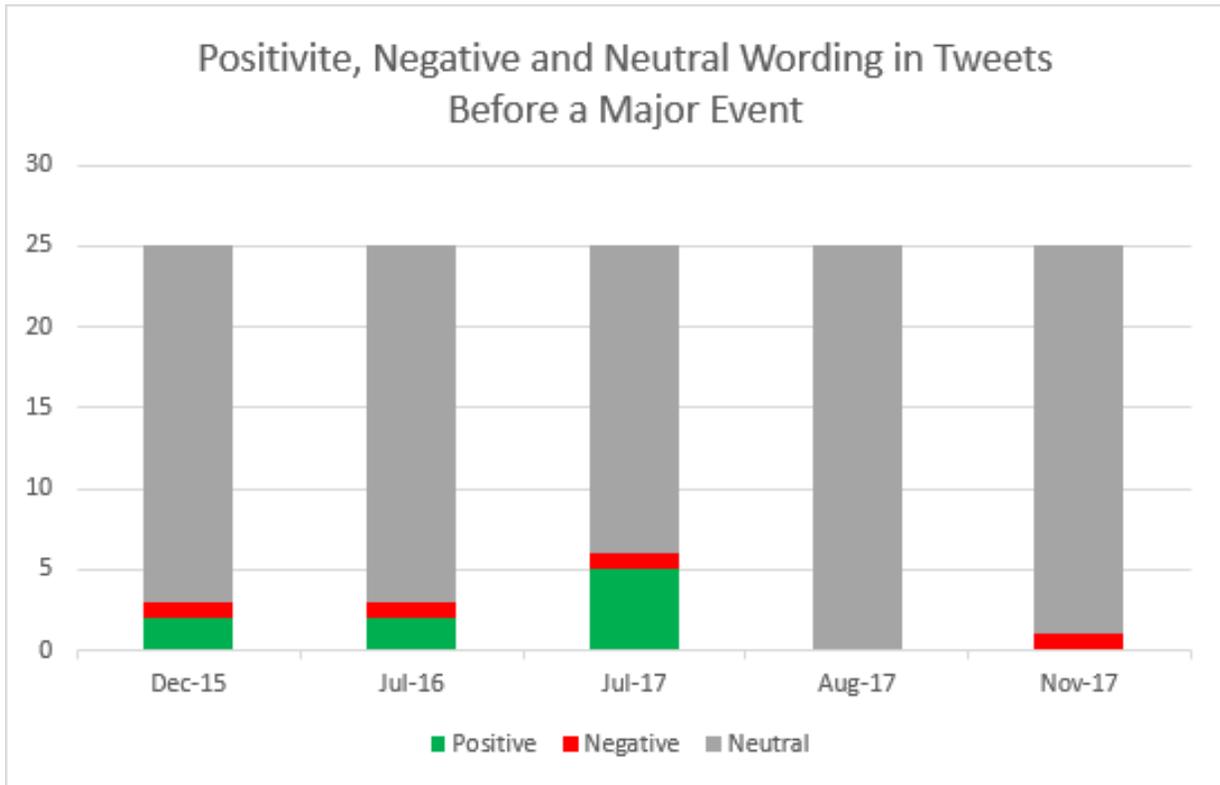


Figure 16: Positively, Negatively, and Neutrally-toned Tweets by Prevalence before a Major Event

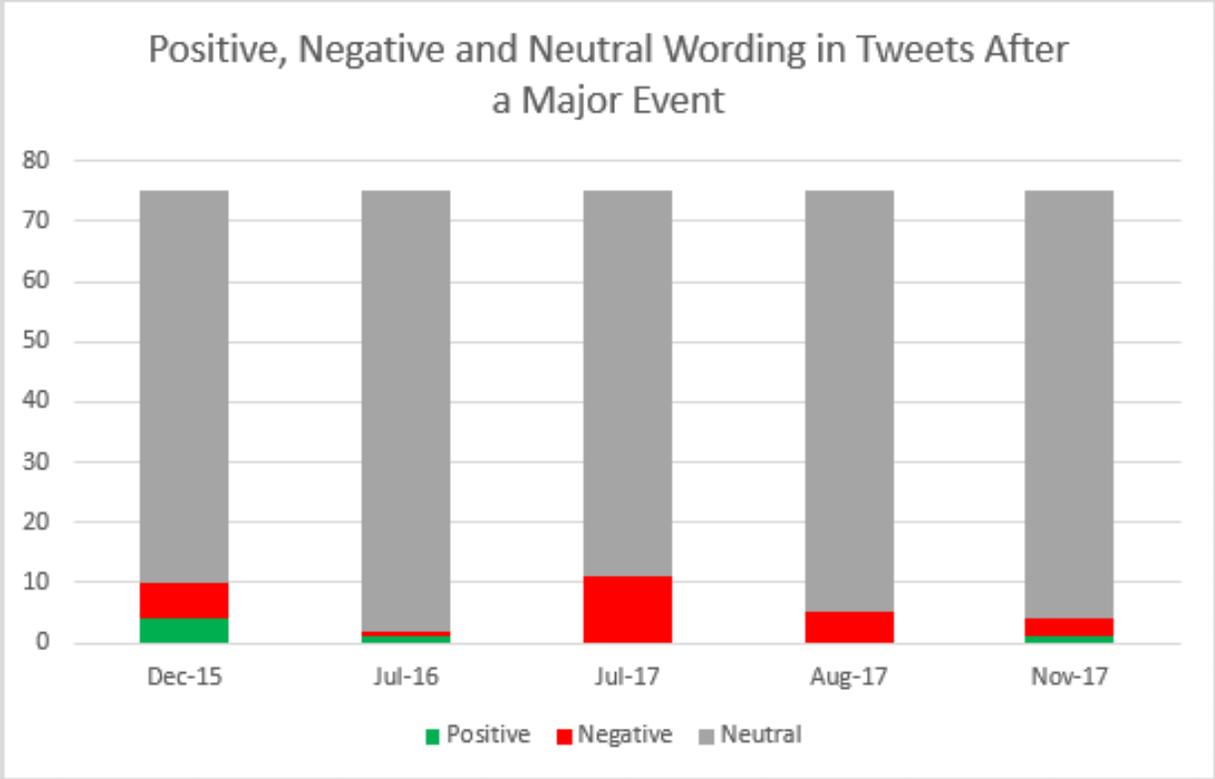


Fig 17: Positively, Negatively, and Neutrally-toned Tweets by Prevalence after a Major Event

Although we hypothesized that the tone that American Twitter users would change before (Figure 16) and after (Figure 17) major news about CRISPR is released, there were no major trends. Although the tone of the analyzed tweets did slightly shift before and after a major events occurred, there were no persistent trends that formed throughout all time periods.

Discussion

Poll Analysis

From analyzing the results found in the poll analysis data, certain conclusions can be found within each section. First, the evolution of opinions supporting genetic modification techniques was seen to follow a decreasing trend over three decades. Second, the poll questions that were phrased using positive syntax and terminology produced higher approval rates than negatively phrased questions. Finally, the demographics of the audience also cause differences in the amount of support that genetic engineering receives. Overall, it can be seen that different factors within the way polling itself is structured results in different outcomes due to underlying influences.

Evolution of Public Opinion

The results found by analyzing the evolution of opinion show that, although there is popular support for genetic engineering, support is slowly decreasing over time. Figure 1 displays this clear trend, starting in the mid-1990s with high public support of inheritable genetic engineering, with the approval percentage ranging from 44-66%, and slowly decreases over time to 4-41% in the year 2003. The waning support trend for genetic engineering appears in opinions on both physical changes and disease prevention applications. There is a difference, however, in the amount of support for each application; people are always less supportive of using genetic engineering for physical characteristic improvements than disease prevention, although that support also decreases over time.

A possible interpretation of this decreasing trend of support could be that a greater amount of knowledge on the part of the public with regard to the genetic engineering technologies leads to better understanding of the associated risks. The more publicly known the technologies become, the more of a reality they become along with the risks associated with the advancements. Whereas in previous years, there may not have been trials and applications of these technologies, and the idea of genetic engineering could have been perceived as more futuristic and optimistic. However, more research would need to be completed in order to fully confirm this interpretation as an explanation of the results.

Public Opinion Based on Syntax

As predicted, the public was more receptive and supportive of questions that used positive words, categorized using Table 1. The most support was typically found in regard to applications to improve health, while most of the public did not support the genetic engineering applications for physical characteristic and appearance improvements. Support was limited for applications used for embryos or that would affect future offspring. These could be interpreted to reflect the morality associated with altering or enhancing a living being without their consent, but also due to the uncertainty of the resulting effects.

These results come with some difficulty, because questions asked about the same features but in different ways and using different language produce different results. According to research, this variation in results based on language is common among poll questions and could decrease the validity of the poll responses (Eplett, 2013; Ferenstein, 2015). This idea is clearly shown in the significant difference between the results of the questions asking about support regarding genetic engineering on an embryo and

applications before birth. For example, the question asking “Do you think that changing the genes of unborn babies to reduce their risk of developing certain serious diseases should be legal?” only gained a support percentage of 26% while the question asking if Americans support germline therapeutic applications had 65% support, as seen in Figure 2 . These two statements, in biological terms, are the same, but the question including the word “unborn” had a lower approval percentage while the questions regarding germline applications had an approval percentage ranging from 26-65%. These results reinforce the idea that language can influence the way the question is interpreted.

Public Opinion Based on Demographics

The results showed that certain demographic factors seem to influence the public’s opinion on genetic engineering, and whether there is support for or rejection of an application. Women are typically less optimistic about the applications than men, displayed in Figure 6, and this shows that they are more cautious with their acceptance and support of technologies that have possible risks to humans. Men still show limited support in all aspects of genetic engineering, but they are typically more concerned about regulatory aspects when it comes to scientific advancements (Weisberg, Badgio, & Chatterjee, 2017).

Religious influences skewed the support toward the conservative side because these technologies are seen as unnatural and “meddling with nature” (Greenwood, 2016). This limited acceptance can be interpreted to reflect the morality associated with all religions. In other words, the type of religious affiliation does not matter, but rather it is the degree of religious commitment of the individual that will determine the amount of support they have for genetic engineering.

For this project’s purposes, the poll analysis data failed to establish any correlation between racial identity and opinions on genetic engineering.

Discourse Analysis of Media

The findings of the analysis made on the six media sources showed results that vary significantly from the hypothesis made at the beginning of this study. The initial hypothesis was that right-leaning sources would include more negative articles than left-leaning sources. This however, proved not to be the case in this study. This hypothesis was made based on the notion that the right wing of the US political spectrum is conservative and heavily associated with conservative Christians. The poll analysis indicated that religious persons are much more likely to disapprove gene modification technologies than non-religious persons. First of all, while there are differences in the presentation of CRISPR from sources of different political bias, the breach is not as big as initially thought. While an initial view of the results may suggest the presence of more purely negative articles, once *The National Review* is separated as an outlier, the number of negative articles becomes comparative smaller to the number of articles with both positive and negative wording and those that are purely positive. This can be seen in the previous section in Figure 8, and the overall leaning of each source can be appreciated on Figure 9, also on the previous section.

Second, the total number of articles that were analyzed were much smaller than expected. The initial number of articles found using the advanced search setting in Google returned about 460 articles that included CRISPR, which was then reduced by eliminating all articles that only included a link to an article on CRISPR or that had no relation to CRISPR. When the articles that only mentioned CRISPR in passing or in relation to studies that did not affect humans were removed, the total number of articles available for review was reduced even further. At the end, only 95 of the initial 460 articles were

considered for analysis (20.65%). Considering the number of articles that mentioned CRISPR in passing or as a reference, and the fact that over half of the analyzed articles only vaguely explain what CRISPR is, we can make the inference that the media may have an implied standard on the public's knowledge on the subject. The consistent use of CRISPR as a reference seems even more disconcerting when the fact that it is only rarely mentioned in titles is taken into consideration. Further studies would be necessary to analyze this discrepancy and are out of the scope of this study.

Thirdly, we can make some assumptions on the level of interest the media sources give to the subject based on both the number of articles as well as the investment placed on the articles. While both of the left-leaning sources (*CNN* and *The New York Times*) and the centrist *CBS News* have their own journalists write the published pieces on CRISPR, both *Fox News* and *USA Today* seem to outsource their CRISPR pieces. This can be taken as a sign that less interest and resources go into writing pieces on this topic. The fact that most of the articles from a different source are taken from centrist authors may also explain the number of mixed and positive articles, as well as the smaller number of negative articles.

On a different note, it is important to remember that even with the pictures that are being told by the media sources, the public that consumes this information does not necessarily have to accept any of the presented information to be true. A 2016 poll by the Pew Research Center shows that public perception of scientists remains low, with only 40% of the American population showing a "good" level of trust on the scientific community (Funk & Kennedy, 2017). This opinion also changes depending on the topic that is being discussed, and while there are no poll numbers for human gene editing as of yet, we can look at other polls on types of genetic modification. For example, Americans have been polled on their level of trust in scientists regarding gene editing in agriculture. In this case, American's trust in scientists and their claims regarding genetically modified organisms (GMOs) is one of the lowest in the poll, with only 37% of respondents trusting scientists' claims about GMO safety (Funk & Rainie, 2017). Trust in media sources is higher, though barely a majority, with 52% of the population "somewhat" trusting national media sources and 20% exhibiting "a lot" of trust (Funk, 2017). These levels of trust also affect how the population reacts to the articles they consume.

Discourse Analysis of Social Media

The most striking pattern in the data found from the analysis of Twitter was that such a high percentage of total tweets (91%) were neutrally-toned. The initial hypothesis was that in a public, casual forum, the typical post about CRISPR would be one that contains the Twitter user's own personal opinion, and that the tone of this opinion could be determined to be positive or negative. What was ultimately found was that the typical post about CRISPR made by an American Twitter user during the selected time periods was a link to an article with a neutrally-toned headline.

For Twitter posts, the format was typically the headline of the article to which the user was linking, followed by a URL and hashtags that related to the article (in the case of this particular analysis, #CRISPR). On many websites, there is a legend containing the logos of several large social media platforms, Twitter typically included. These logos are links to the social media websites, which, if a user is logged in, will create a tweet with a link to the website the user wanted to share. These "shared" posts have very similar formats designed for each social media platform. Oftentimes, the tweets contained within the category "broadcast" seemed to be the result of one of these share functions, and if not the result of one of them, then certainly created in a very similar fashion. The significance of this is that it reveals how American users appeared to have typically posted to Twitter about CRISPR through news

websites (56.8%), research articles (14.8%), and blogs (9.8%) they visited during the time periods selected. They then posted a link without adding their own opinion (325 of the total 500 tweets analyzed). Thus, out of the 325 “broadcast” category tweets, 299 tweets (92%) are articles that have neutrally intoned headlines. This is significant because these “broadcasts” are simply articles Twitter users have chosen to link during the analyzed time periods.

As American Twitter users who were discussing CRISPR during the time periods analyzed used links to news articles to talk about CRISPR an analysis on the discourse surrounding CRISPR on Twitter is only complete with the context of the American news media and how American news media discusses CRISPR (pages 43-44). We found that only 7.4% of the articles analyzed contained the word CRISPR in the title. In contrast, our discourse analysis of Twitter revealed that 390 (78%) of the analyzed tweets contained the word CRISPR in the body. The sharing of articles that contain the word “CRISPR” in the title generates tweets that contain CRISPR in the body, thus, the major discrepancy between the percentage of analyzed tweets containing the word CRISPR and the percentage of analyzed news with the word CRISPR in the title indicates that Twitter users, when choosing articles to share, are selective.

Further comparison between news discourse and Twitter discourse also shows that, although there were trends in the tone of complete news articles over time, tweets did not show any considerable trends during the selected time periods. For example, when the bioethics conference of December 2015 was occurring, the majority of news articles included in our analysis were negatively-toned, while only 6% (of tweets analyzed from December 1-24, 2015) of tweets analyzed contained negative tone. And, due to the prevalence of Twitter users who simply linked to articles our analysis shows that the users who posted tweets selected news articles with neutrally-toned headlines to share (76% of tweets analyzed during that time period). Only three tweets during that time period (December 1-24, 2015) even link to articles with negatively-toned headlines. Further research into the ways that American Twitter users select articles to share would be prudent, given this information, but would be beyond the scope of this project. A possible way to conduct this research would be to code articles that Twitter users link to during the selected time periods, as to gain more information as to what content people are sharing on Twitter.

To gather more insight into what Americans feel about CRISPR, a further analysis of the articles that Americans link on Twitter about CRISPR should be conducted. In particular, the prevalence of sources and how much the American public believes them should be investigated. Because of the dependence on these articles for the Twitter discourse, the content of the articles themselves are vital for understanding the Twitter discourse surrounding CRISPR.

Unfortunately, the coding instrument was not able to interpret tone effectively in every tweet, such as in cases of perceived sarcasm or nuanced arguments; rather the instrument focused on the appearance of key words and phrases. Due to the character limit on Twitter posts (140 characters during the selected time periods), and the tendency of Twitter users to simply repeat the headline or title of the media to which they were linking, the amount of nuanced arguments about CRISPR on Twitter were limited. Of the positively- and negatively-toned tweets, negatively-worded tweets accounted for twice the volume of tweets (30) than positively-worded tweets did (15). This, of course, is relative to the 455 neutral tweets.

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Appendix A: Coding Instrument for Media Analysis

The original number of articles was first refined by eliminating all duplicate articles, and then all articles where the subject of CRISPR was only mentioned in passing and those that mentioned CRISPR in a context that did not involve human therapies or trials.

Each of the articles analyzed were then coded according to the following coding instrument:

1. Is the word CRISPR used in the title?
 - a. Yes
 - b. No
2. Is the specific CRISPR technique mentioned? (e.g. Cas9, Cas13)
 - a. Yes
 - a. If yes, write down which one
 - b. No
3. Does the article explain what CRISPR is?
 - a. It gives a good fundamental explanation (e.g. goes into the steps of the procedure, explains the “cut and paste system” in easy to understand terms)
 - b. It gives a vague explanation (e.g. “molecular scissors”, “a genetic therapy”)
 - c. It does not explain what CRISPR is
4. Does the article mention science fiction works as a comparison ?
 - a. Yes
 - a. Write down which one(s)
 - b. No
5. Does the article use positive words to describe CRISPR? (e.g. groundbreaking, life saving, cheaper, faster, revolutionary, highly precise)
 - a. Yes
 - b. No
6. Does the article use negative words to describe CRISPR? (e.g. problematic, controversial, scientists are playing god, designer babies)
 - a. Yes
 - b. No
7. Does the article include both positive and negative words?
 - a. Yes
 - a. If yes, remove article out from this analysis, and document it in excel spreadsheet
 - b. No
8. What is the main topic of the article?
 - a. Controversy/ethics of CRISPR
 - b. Review of medical trials using CRISPR
 - c. Reporting a new discovery about CRISPR or made using CRISPR\

9. Does the article mention a new discovery, study or paper?
 - a. Yes
 - b. No
 - c. 9.1 Does the article mention a new discovery?
 - b. Yes
 - c. No
10. 9.1.1 Were the scientists/groups behind the discovery mentioned?
 - a. Yes, the people/groups responsible were mentioned
 - b. Only the country/region where the discovery was made was mentioned
 - c. No credit was given for the discovery
 - d. 9.2 Does the article mention a new study or paper?
 - a. Yes
 - d. No
 - e. 9.2.1 Were the scientists/institutions behind the study/paper mentioned?
 - a. It mentions the authors (specific people and group) and institutions
 - b. It mentions the authors only
 - e. It mentions only the institution behind it (a University, research group, pharmaceutical company, etc)
 - f. It mentions only the country/region
 - g. It does not mention any of the above
 - f. 9.2.3 Is the paper/study source given?
 - a. It mentions where the paper/study was published
 - b. It does not mention where the paper/study was published
11. Does the article mention “embryos”?
 - a. Yes, in the context of research/studies done on embryos
 - b. Yes, in the possibility of editing embryos
 - c. No
12. Does the story mention future uses of CRISPR?
 - a. Yes
 - b. No
 - c. What tense is used when discussing the future uses of CRISPR?
 - b. Present
 - c. Future
 - d. The wording is confusing, it is hard to tell if the uses cited in the article are a current reality or if they are achieved potential, future advancement.
13. Did a journalist employed by the news source write the article, or was the article written by a journalist from another source?
 - a. From the source
 - b. Taken from another source (write down the source)
14. Did the article mention Dr. Jennifer Doudna?
 - a. Yes
 - b. No

This coding instrument was evaluated by the three members of the team. In order to do this, the instrument first went through multiple drafts based on preliminary research on what was generally included in the articles that were to be evaluated. Once the instrument was deemed satisfactory, the team met and evaluated an article as a group in order to clarify any questions on the language or particulars of the code. Then two members were given an additional four articles to code on their own. We then compared each set of to insure consistency within our own analysis, and to allow for replication of the study using the same coding instrument. This comparison yielded a high percentage of similarity, with only a difference in interpretation on [TS4] article over the clarity of the definition of CRISPR, and one disagreement over the ambiguity of the tense in another one. Thus, the coding instrument was deemed acceptable and data collection was initiated.

Appendix B: Coding Instrument for Twitter Analysis

1. Is the word CRISPR used in the tweet?
 - a. Yes
 - b. No
2. Does the tweet use positive words to describe CRISPR? (according to the table)
 - a. Yes
 - b. No
3. Does the tweet use negative words to describe CRISPR? (according to the table)
 - a. Yes
 - b. No
4. What category of tweet is this?
 - a. Informational (has facts about a subject, goal is to familiarize public with information)
 - b. Community (tweets used to engage users of the community)
 - c. Action (tweet includes references to actions the reader should take in real life i.e. ‘Sign my petition’)
 - d. Opinion (tweet is an expression of a feeling about CRISPR i.e. ‘I hate CRISPR, I have nothing but disdain for it.’)
 - e. Broadcast (tweet does not express any new sentiment, simply broadcasting another person’s message, retweets without comment are all broadcast type tweets)
 - f. Inquisitive (tweet is written by the author with the intention of another person giving them a specific piece of information i.e. ‘@Joe6Pack What do you think of this?’, ‘How does CRISPR work? Can anyone tell me?’)
5. Is the tweet a reply to another tweet?
 - a. Yes
 - i. What category tweet was that tweet?
(Refer to item 4 for tweet categories.)
 - b. No
6. What is the topic of the tweet?
 - a. CRISPR’s therapeutic uses in adults
 - b. CRISPR’s therapeutic uses in embryos
 - c. The use of CRISPR to ensure aesthetic traits in embryos
 - d. The use of CRISPR on animals
 - e. Other (Write down topic)
7. Does the tweet have a link to a source/topic of discussion?
 - a. Yes, the tweet links to an academic paper/journal/study on CRISPR
 - b. Yes, the tweet links to a newspaper article on CRISPR
 - c. Yes, the tweet links to a blog
 - d. No, the tweet does not contain a link

This coding instrument was evaluated by three members of the team by drafting a coding instrument based off of the coding instrument for media analysis, but then specialized for Twitter through the use of academic papers on the use of social media for conclusive social data (Lovejoy and Saxton 2012). The paper recommended sorting posts into categories, of which they gave three, and three were invented for Twitter specifically, additionally, the topic of the tweet and whether or not the tweet had a link were considered. All three group members were given this revised coding instrument, and coded 15

pre-selected tweets picked on the basis of their diversity in topic, tone, and lucidity. When the results of these coded tweets were compared to test consistency, the only differences found were in the accidental inclusions of words that were similar to words in the table of positive and negative terms and a few subjective differences in category. The coding instrument was sufficiently consistent, so it was used to gather data.