AI and Human Enhancement: Examining Attitudes on Neural Chips and Embryonic Gene Editing

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Introduction

Artificial intelligence (AI) has evolved to encompass a wide array of applications, permeating various aspects of our daily lives. Its prevalence is undeniable, marking a significant shift in how we interact with technology. Particularly noteworthy is the remarkable progress AI and technology have made within the healthcare sector. Yet, amidst these advancements, concerns persist regarding the safety and ethical implications of integrating AI into healthcare practices. Such considerations underscore the importance of critically examining public sentiments surrounding AI in healthcare. Understanding these sentiments is pivotal, as they can shape the widespread adoption of AI, determine its intended purposes, guide investment decisions, and inform communication strategies within the scientific community.

The American Trends Panel (ATP), administered by the Pew Research Center in November 2021, sought to understand public sentiment towards different topics in AI. The survey comprised a representative sample of randomly selected U.S. adults; through two surveys with multiple waves, respondents were polled on their opinions about a spectrum of AI-related topics, ranging from autonomous vehicles to medical innovations. In this paper, we utilize this Pew data to explore whether individuals' attitudes towards one topic of AI in healthcare could predict their opinions on another AI healthcare topic. Specifically, we focused on two prominent healthcare domains: neural implants and gene editing. These topics both hold significant potential for enhancing health outcomes, but both are divisive and garner considerable attention in the media. By investigating correlations between attitudes towards different AI applications in healthcare, we aimed to gain a deeper understanding of public perceptions and their implications for the future of AI integration in the medical field (Tyson et al., 2022).

We began our exploration of this topic with a literature review to understand current research and sentiment findings related to neural implants and gene editing. We then performed a sentiment analysis of Reddit forum posts utilizing natural language processing to better understand whether the attitudes noted in the literature are reflected in the opinions expressed on the forums. We began our quantitative analysis with several explanatory linear regression models and finally branched into predictive modeling utilizing decision trees and random forests.

Literature Review

The consensus within the scientific community, as articulated in the article *CRISPR in context: towards a socially responsible debate on gene editing* by Morrison and de Saille (2019), is that human genetic germline editing presently lacks the safety assurances requisite for broad application. Scientific caution is complemented by public indecision; in the paper *Prevailing public perceptions of the ethics of gene therapy* by Robillard et al. (2014), 467 individuals were polled about their opinions regarding gene editing; while the surveyed respondents expressed their support for genomic editing in instances of "serious" diseases such as Alzheimer's, their enthusiasm notably waned when considering gene therapy for "nonserious" conditions like ADHD. Additional research, presented in the paper *U.S. attitudes on human genome editing* by Scheufele et al. (2017), corroborated these opinions with limited endorsement for interventions targeting less severe ailments or enhancements for individuals without underlying health concerns. Notably, this publication found public support for gene editing to treat serious conditions for both germline (heritable) and somatic (nonheritable) gene editing. Principal among the concerns expressed by participants in both surveys were considerations pertaining to treatment efficacy and equity, reflecting a nuanced stance toward the ethical dimensions of genetic intervention. Additionally, a discernible positive trend toward acceptance of gene editing practices has been observed from the 1990s to contemporary times.

Findings regarding demographics and attitudes toward gene editing were mixed. Robillard et al. (2014) note in *Prevailing public perceptions of the ethics of gene therapy* that they found an absence of a direct correlation between specific demographic variables and attitudes toward gene editing; in contrast, religious identification emerged as a mitigating factor in *U.S. attitudes on human genome editing* findings, with religious individuals displaying a reduced propensity for supporting genetic intervention. The cultivation of a public consensus around gene editing faces multifaceted challenges, including the tendency to marginalize lay opposition as irrational or uninformed, the compartmentalization of technical evaluations from ethical deliberations, and the prevalent tendency to treat each technological advancement as an isolated ethical quandary devoid of broader contextual considerations encompassing scientific progress, funding dynamics, and commercial interests.

Research indicates similar nuanced opinions regarding neural implants. Lahr et al. (2015)'s survey of 131 ALS patients indicated a considerable familiarity among respondents with brain-machine interface (BMI) technology, coupled with a predominantly positive disposition towards its potential applications. In Reinares-Lara et al. (2018) paper *Do you want to be a cyborg? The moderating effect of ethics on neural implant acceptance*, the survey responses revealed a notable proportion of respondents expressing either indifference or outright support for implants. Social dynamics and affective states emerged as pivotal influences shaping attitudes toward memory implants across diverse demographic cohorts. Specifically, Reinares-Lara et al. (2018) note that positive emotions and social influences significantly influenced the intention to utilize memory implants across all groups surveyed.

However, while performance expectancy, indicative of a belief in the technology's efficacy, demonstrated a discernible impact on intention to use memory implants within cohorts opposed to their implementation, negative emotions and anxiety did not significantly factor into individuals' decision-making processes.

Sentiment Analysis

Based on this previous research and its findings on public perceptions of both neural implants and gene editing, we further assess public opinions on these two medical AI technologies by conducting a sentiment analysis using Reddit data. In contrast to survey research, this method allows us to gain an even deeper understanding of public support or distrust of AI healthcare applications because commenters on Reddit posts can be expected to express their current sentiment without being subjected to a research environment. By utilizing this data, we avoid common confounders of survey research, such as respondents' attempts to answer the question in line with the researchers' expectations, their decision to give socially desirable answers to questions about sensitive topics (Dafoe et al., 2015), or their tendency to choose the median answer choice to avoid selecting clearly defined positive or negative answer choices.

In this part of our study, we analyzed public sentiment toward gene editing and CRISPR technologies using data sourced from Reddit. To gather a comprehensive and relevant dataset, we collected post titles from various high-activity subreddits and refined our search using the "relevant" setting with the keywords "gene editing" and "CRISPR".

Variable Selection

Sentiment classification of Reddit post titles was performed using the TextBlob Python package, which employs a polarity score to categorize sentiments. Titles with a polarity score less than zero were classified as negative, those with a score of zero as neutral, and those with a score greater than zero as positive. This method allowed us to segment the data into clear affective categories reflecting different levels of acceptance or resistance toward gene editing technologies.

Empirical Strategy

We applied linear regression models to each sentiment category, analyzing data from the years 2014 to 2024, to examine temporal trends. This approach aimed to identify whether there were statistically significant changes in sentiment over time, which could suggest evolving public attitudes.

Results

Our regression analysis revealed:

- **Negative Sentiment:** No statistically significant change was observed over time, indicating a consistent level of criticism or skepticism on Reddit.
- **Neutral Sentiment:** A statistically significant increase in neutral sentiment was observed, suggesting an increasing tendency among Reddit users to maintain or express more neutral opinions over time.
- **Positive Sentiment:** There was a statistically significant decrease in positive sentiment, indicating a decline in acceptance or approval of gene editing technologies among Reddit users.

These results indicate that while overall sentiment on Reddit is showing a significant increase in neutrality, this could reflect the specific subreddits from which the data was drawn. The observed statistical significance in the neutral category underscores a potential shift towards more balanced views, possibly influenced by the evolving discourse on gene editing technologies. Additionally, the notable decrease in positive sentiment highlights a decline in outright approval or acceptance, which might suggest a growing complexity or critical stance in the discussions surrounding gene editing technologies.

The insights from this sentiment analysis are preliminary yet crucial for understanding the broader dynamics of public opinion. They serve as a foundation for further investigation into how such emerging technologies are perceived and discussed across different public forums.

Table 1: Regression Analysis of Attitudes Toward Gene Editing on Reddit

	Dependent Variable		
Variable	Negative Ratio	Positive Ratio	Neutral Ratio
Intercept	-1.778 (SE = 3.355, p = 0.609)	17.166* (SE = 7.231, p = 0.0416)	-14.388 (SE = 6.489, p = 0.0538)
Year	0.000943 (SE = 0.00166, p = 0.584)	-0.008313* (SE = 0.00358, p = 0.0454)	0.007370* (SE = 0.00321, p = 0.0475)
Observations	600	600	600
R^2	0.03452	0.3744	0.3688
Adjusted R^2	-0.07276	0.3049	0.2987
Residual Std. Error	0.01743 (df = 9)	0.03756 (df = 9)	0.03371 (df = 9)
F Statistic	0.3218 (df = 1; 9, p = 0.5844)	5.387* (df = 1; 9, p = 0.04541)	5.259* (df = 1; 9, p = 0.04752)

These findings of public sentiments toward emerging technologies, and our identification of a potential shift towards more polarized views appear to confirm our initial assumption that the general public can be expected to have distinct opinions on neural implants and gene editing. Building on this expectation, we began exploring the data from Pew Research Center's surveys on AI and human enhancement(Tyson et al., 2022).

Explanatory Models

As a first step in our analysis we tested the relationship between respondents' attitudes on neural chip implants and embryonic gene editing using a linear modeling approach. We selected two response pairings, GENEV3 and BCHIP3, and GENEV4 and BCHIP14 to test our hypothesis that respondent opinions on neural implants have an effect on their opinions on embryonic gene editing. We selected this modeling strategy to test whether there is a statistically significant effect of the independent and dependent variables within our two pairings of variables of interest, which warrants further exploration through predictive modeling.

Variable Selection

We opted to divide our primary analysis into two segments for both the explanatory and predictive models. We chose two sets of questions from the ATP: BCHIP3[1] and GENEV3[2], and BCHIP14[3] and GENEV4[4]. These pairings were selected for their complementary nature. The first pair framed the inquiry into AI adoption in terms of personal benefit, while the second pair framed it in terms of morality. Our literature review highlighted these as the most significant factors influencing an individual's propensity to endorse medical AI intervention, such as neural implants or gene editing. As an additional variable, we also included the variable SC1[5] to assess whether respondents' general opinions about scientific advances are

[1] Would you personally want a computer chip implant in the brain, allowing you to far more quickly and accurately process information, if you had the opportunity? (a) Definitely want; (b) Probably want; (c) Probably NOT want; (d) Definitely NOT want

[2] If gene editing to greatly reduce a baby's risk of developing serious diseases or health conditions over their lifetime were available, is this something you would want? (a) Yes, I would definitely want this for my baby; (b) Yes, I would probably want this for my baby; (c) No, I would probably NOT want this for my baby; (d) No, I would definitely NOT want this for my baby.

[3] Computer chip implants in the brain could be used for a number of purposes. Would you favor or oppose the use of computer chips implants in the brain for each of the following purposes? (a) To treat age-related decline in mental abilities; (b) To allow increased movement for people who are paralyzed; (c) To make it possible for thoughts in the brain to search content on the internet without typing; (d) To translate thoughts in the brain, without speaking, into text on a screen.

[4] If the use of gene editing to greatly reduce a baby's risk of developing serious diseases or health conditions over their lifetime becomes widespread, do you think each of the following would happen? (a) Even if gene editing is used appropriately in some cases, others would use these techniques in ways that are morally unacceptable; (b) These gene editing techniques would help people live longer and better quality lives; (c) Development of these gene editing techniques would pave the way for new medical advances that benefit society as a whole; (d)These gene editing techniques would go too far eliminating natural differences between people in society.

[5] Overall, would you say science has had a mostly positive effect on our society or a mostly negative effect on our society?

considered to be beneficial to society. We include this variable as a predictor in two additional explanatory models and test its relationship on BCHIP3 and GENEV3.

Empirical Strategy

We began by examining the impact of attitudes towards survey question BCHIP3 on the attitudes of GENEV3. These questions were juxtaposed due to their element of perceived personal benefit, along with similarities in the possible responses. GENEV3 asked individuals whether they would opt for gene editing to significantly decrease the likelihood of their child developing severe illnesses or health issues. BCHIP3 delved into participants' inclination to adopt neural implants to enhance their cognitive abilities. Our aim was to examine whether the favorable attitudes identified in the literature (particularly when individuals perceived personal benefits) remained consistent with our dataset.

Our second set of questions for analysis comprised GENEV4 and BCHIP14. GENEV4 delved into inquiries about gene editing within a moralistic context, offering response options such as "[gene editing would be] morally unacceptable," "[gene editing would go] too far," "[gene editing would provide] Benefit to society," or "[gene editing would provide] a better quality of life." In contrast, BCHIP14 explored a range of potential applications for neural implants, including treating age-related mental decline, enhancing movement for paralyzed individuals, enabling thought-based internet searches, and facilitating thought-based translation without speech. We found these neural chip applications to be diverse and open to varying interpretations, potentially yielding different effects on GENEV4 compared to our initial set of questions.

Referring to our literature review, we hypothesized that medical AI intervention would receive strong support when perceived as medically necessary but encounter less endorsement when seen as a frivolous or unnecessary enhancement. By examining the impact of different neural enhancement applications alongside gene editing, we aimed to determine if we could replicate this pattern for "less serious" uses of neural implants.

Additionally, we incorporated a logistic regression model for comparative analysis, outlined in the appendix. Noteworthy divergence between the logistic and linear regression findings was observed, particularly concerning the stability of outcomes across BCHIP14a, b, c, and d variables. Specifically, the logistic regression model consistently indicated a significant correlation between attitudes toward gene editing and neural implants across all mentioned variables. Conversely, the linear regression model exhibited greater variability in the significance of these associations across the same variables.

Results

Table 1 presents the results for our two main explanatory models, where we tested the relationships between our two pairings of interest.

When assessing the relationship between our first pairing of variables, BCHIP3 (would you personally want a computer chip implant in the brain, allowing you to far more quickly and accurately process information if you had the opportunity?) and GENEV3 (If gene editing to greatly reduce a baby's risk of developing serious diseases or health conditions over their lifetime were available, is this something you would want?) we find a positive and statistically significant effect. This effect is in line with our expectations because respondents who support the enhancement of their own cognitive abilities through neural chip implants can be expected to support the elimination of potential health risks for their babies through gene editing. Respondents can be expected to be generally supportive of technological advances to improve their own and their baby's abilities and health.

As a next step, we assessed the relationship between the second pairing of variables, GENEV4 and BCHIP14. While BCHIP14a (opinions on treating age-related decline in mental abilities) does not have a statistically significant effect on respondents' opinions on GENEV4a (even if gene editing is used appropriately in some cases, others would use these techniques in ways that are morally unacceptable), BCHIP14b and c have a statistically significant effect. The lack of a statistically significant effect of BCHIP14a on GENEV4a may be caused by the differences in framing of the two questions. Respondents' views of the potential of neural implants' ability to help treat an age-related decline in mental abilities do not influence their opinions on whether gene editing may be misused despite its possible justification in other areas. Respondents' opinions on BCHIP14b (chips could help improve movement for paralyzed patients) have a positive and statistically significant effect on GENEV4a opinions, which assess whether respondents believe gene editing could be used for morally unacceptable goals. While this effect may be surprising at first glance, it may be explained by the ability of chip implants to restore movement, thereby allowing a clearly defined demographic to regain a higher quality of life, while gene editing techniques may be used on a less clearly defined demographic and thereby hold the potential for misuse of the technology for less morally acceptable means. Respondents who do support chip implants for paralyzed patients may not generally support technological enhancement of human performance but rather see a potential for misuse. The effect of BCHIP14c (make it possible for thoughts in the brain to search content on the internet without typing) is negative and statistically significant on GENEV4a, which is in line with our expectations. Respondents who support this type of enhancement are less likely to see gene editing as potentially morally problematic because they support "less serious" uses of neural implants. Finally, the effect of BCHIP14d (translate thoughts in the brain, without speaking, into text on a screen) is negative but not statistically significant.

Respondents' opinions on neural implants that are captured in BCHIP14a-d have positive and statistically significant effects on respondents' opinions on GENEV4b (gene editing techniques would help people live longer and better quality lives). These positive and statistically significant effects are in line with our expectations. Respondents who support neural implants to combat an age-related decline, improve the movement of paralyzed patients, allow for internet searches without typing, and translate thoughts into text on the screen are likely to believe that gene editing techniques can help people live longer and enjoy a better quality of life since they are generally supportive of technological and scientific advances to

Table 2: The Relationship of Respondents' Opinions on Chip Implants on Embryonic Gene Editing

	Dependent variable:				
	GENEV3	GENEV4a	GENEV4b	GENEV4c	GENEV4d
	(1)	(2)	(3)	(4)	(5)
BCHIP3	0.368***				
	(0.012)				
BCHIP14a		0.001	0.177***	0.182***	−0.035*
		(0.018)	(0.018)	(0.019)	(0.020)
BCHIP14b		0.178***	0.145***	0.109***	0.156***
		(0.021)	(0.021)	(0.022)	(0.023)
BCHIP14c		−0.090***	0.090***	0.094***	−0.066***
		(0.015)	(0.014)	(0.014)	(0.017)
BCHIP14d		−0.004	0.082***	0.082***	−0.030*
		(0.014)	(0.014)	(0.014)	(0.017)
Constant	0.839***	2.124***	0.810***	0.931***	2.053***
	(0.034)	(0.045)	(0.045)	(0.046)	(0.048)
Observations	3,879	4,765	3,992	4,106	3,975
Log Likelihood	−4,063.572	−4,590.100	−3,353.568	−3,641.595	−4,001.396
Akaike Inf. Crit.	8,131.144	9,190.199	6,717.136	7,293.191	8,012.791
Note:					*p<0.1; **p<0.05; ***p<0.01

improve the quality of life.

When it comes to respondents' opinions on GENEV4c (development of these gene editing techniques would pave the way for new medical advances that benefit society as a whole), the effects are also positive and statistically significant for all four BCHIP14 opinions. Respondents believe that gene editing can benefit society as a whole, and this belief is tied to respondents' support of neural chip implants to improve the health and performance of human beings.

In contrast to our previous findings, BCHIP14a, b, and d have a negative and statistically significant effect on respondents' opinions on GENEV4d (gene editing techniques would go too far, eliminating natural differences between people in society). Respondents who support chip implants to treat age-related decline in mental abilities, restore movement of paralyzed patients, and support the translation of thoughts into text on a screen are less likely to believe that gene editing would go too far and eliminate natural differences between people in society. This is in line with our expectations because all three chip applications aim to improve the abilities of persons who suffer from health-related impairments. Patients who suffer from an age-related decline, are paralyzed or even locked-in, and are unable to communicate will gain back abilities through neural chip implants. Respondents who support these types of applications can be expected to view the associated elimination of individual disadvantages as a good thing and, therefore, do not believe that gene editing is likely to go too far and will eliminate natural differences in society. Respondents' opinions on BCHIP14b, however, are positive and statistically significant for opinions that gene editing may eliminate natural differences in society. This may be caused by respondents supporting a "less serious" use of neural implants while being cognizant of the potential dangers of technological advances that are achieved through excessive improvements.

Table 2 presents the results of our additional control explanatory models. In these models, we tested the relationship between respondents' opinions on scientific advancements, in general, using the SC1 variable (Overall, would you say science has had a mostly positive effect on our society or a mostly negative effect on our society?) and their opinions on BCHIP3 and GENEV3, computer chip implants to enhance cognitive abilities and gene editing to prevent serious health risks for their babies. The effects are positive and statistically significant, which confirms our assumption that a person's opinion on whether scientific advances are to the benefit of society has an effect on whether they are supportive of chip implants or gene editing to the benefit of the individual.

Table 3: Respondents' Opinions on Scientific Advancements and their Effect on Opinions on Chip Implants and Embryonic Gene Editing

	Dependent variables:	
	BCHIP3	GENEV3
	(1)	(2)
SC1	0.305***	0.366***
	(0.021)	(0.020)
Constant	1.912***	0.890***
	(0.058)	(0.055)
Observations	5,107	3,879
Log Likelihood	−6,676.807	−4,354.952
Akaike Inf. Crit.	13,357.610	8,713.905
Note:	*p<0.1; **p<0.05; ***p<0.01	

Our explanatory models confirmed that our selection of independent and dependent variables appears to be suitable for our further exploration through predictive modeling.

We also add a logistic regression model for comparison. This is located in the appendix. The difference in the results of the logistic regression and the linear regression were that the logistic regression model showed stable results accross BCHIP14a, b,c and d showing a stable relationship between gene editing attitudes and neural implant attitudes compared to the linear regression model which had more variability across these variables.

Empirical Strategy

Our predictive modeling comprised two parts. Initially, we constructed a single decision tree to assess the impact of our independent variables on our dependent variables. Subsequently, we conducted a random forest analysis to evaluate potential disparities in statistical significance and improvements in misclassification rates. We utilized this two-step approach for the predictive modeling of our two question pairings (GENEV3 and BCHIP3 and GENEV4 and BCHIP14) and further applied the same strategy to our supplementary analyses of opinions on whether scientific advances benefit society and whether whether demographic characteristics influence respondents' opinions on neural implants and gene editing.

Our dataset contained a total of 5107 responses to the chosen questions. We divided the dataset into training and testing sets to build and evaluate our models. Specifically, 75% of the observations (3830 responses) were allocated for training, while the remaining 25% (1277 responses) were set aside for testing. The single decision tree and random forest models were trained using this split. We configured the random forest models to comprise 5000 trees each. This choice of tree number aimed to capture diverse patterns in the data while balancing computational resources.

Gene editing and neural implants: Personal Impact

We began by examining the relationship between BCHIP3[6] and GENEV3[7]. Our single decision tree can be seen below (Figure 2), along with the confusion matrix (Table 4).

[6]Would you personally want a computer chip implant in the brain, allowing you to far more quickly and accurately process information, if you had the opportunity? (a) Definitely want; (b) Probably want; (c) Probably NOT want; (d) Definitely NOT want

[7]If gene editing to greatly reduce a baby's risk of developing serious diseases or health conditions over their lifetime were available, is this something you would want? (a) Yes, I would definitely want this for my baby; (b) Yes, I would probably want this for my baby; (c) No, I would probably NOT want this for my baby; (d) No, I would definitely NOT want this for my baby.

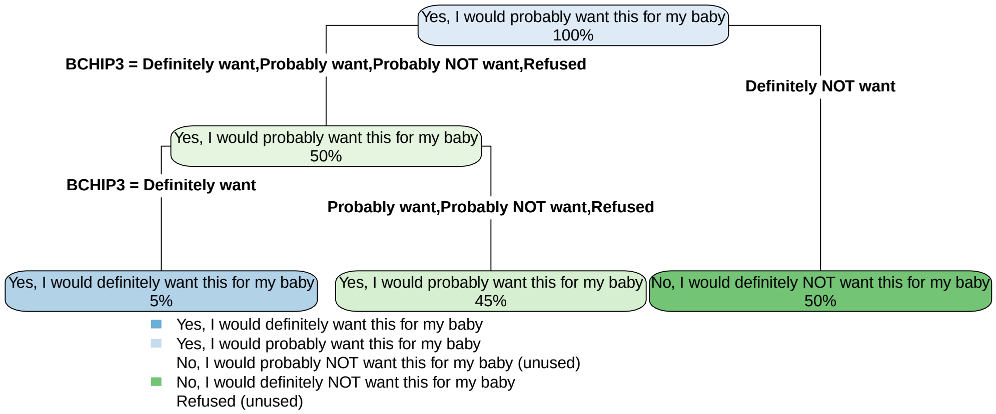

Figure 1: Decision Tree GENEV3 and BCHIP3

Table 4: Confusion Matrix GENEV3 and BCHIP3

	A	B	C	D	E
Yes, I would definitely want this for my baby	46	107	0	48	0
Yes, I would probably want this for my baby	21	271	0	156	0
No, I would probably NOT want this for my baby	3	128	0	176	0
No, I would definitely NOT want this for my baby	1	40	0	245	0
Refused	1	15	0	19	0

Note: A: Yes, I would definitely want this for my baby; B: Yes, I would probably want this for my baby; C: No, I would probably NOT want this for my baby; D: No, I would definitely NOT want this for my baby; E: Refused

We ran the misclassification rate of the decision tree and found a rate of 0.559906 (approximately 56%) The confusion matrix shows that the decision tree model did not accurately predict the *No, I would probably NOT want this for my baby* and *Refused* categories. The model performed best in predicting the *No, I would definitely NOT want this for my baby* category, and had a considerable number of accurate predictions for the *Yes, I would probably want this for my baby* category. However, as we can see from the number of misclassifications, the model made several inaccurate predictions.

We then used the random forest algorithm to assess whether there would be any enhancement in model accuracy. Initially employing 5000 trees, we noticed a rise in the model's error rate to 0.5606891. This prompted us to speculate that the excessive number of trees might be overfitting our dataset. Subsequently, we adjusted the number of trees in the random forest to 500, 100, and 10. However, we still encountered the same error rate even with these modifications. This observation led us to consider that the inaccuracies might stem from inherent variations in the data and a restricted range of predictive and dependent variables.

Table 5: Confusion Matrix Random Forest GENEV3 and BCHIP3

	A	B	C	D	E
Yes, I would definitely want this for my baby	46	107	0	48	0
Yes, I would probably want this for my baby	21	268	0	156	3
No, I would probably NOT want this for my baby	3	124	0	176	4
No, I would definitely NOT want this for my baby	1	36	0	245	4
Refused	1	13	0	19	2

Note: A: Yes, I would definitely want this for my baby; B: Yes, I would probably want this for my baby; C: No, I would probably NOT want this for my baby; D: No, I would definitely NOT want this for my baby; E: Refused

Gene editing and neural implants: Moralistic Framing

For the second pair of questions, we used each sub-question of the GENEV4 question as a dependent variable for a tree model and all sub-questions of BCHIP14 as predictor variables for each model. In this way, we hoped to capture different effects of the moralistic framework of these questions in our results.

GENEV4_A and BCHIP14

The sub-question GENEV4_A asks respondents how likely gene editing is to be abused in ways that "are morally unacceptable." After running our initial tree, we found that BCHIP14_C[8] was the only statistically significant variable in answering this question.

[8] [Would you be more or less likely to support the use of neural implants]...to make it possible for thoughts in the brain to search content on the internet without typing?)

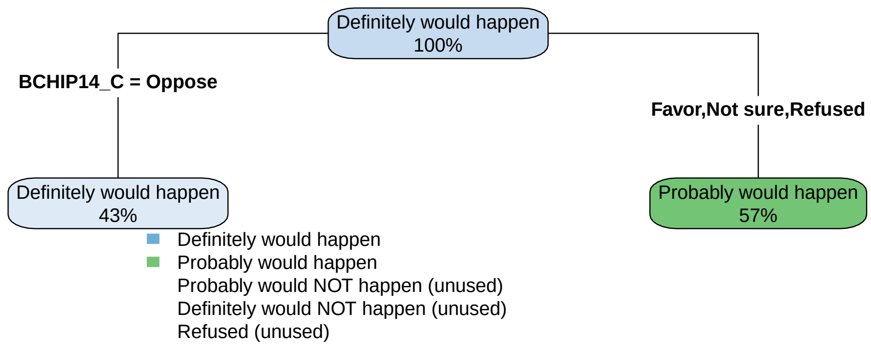

Figure 2: GENEV4_A and BCHIP14

We ran the misclassification rate of the single decision tree and it returned a rate of 0.4839468 (approximately 48%). We can see from the confusion matrix that the model did not accurately predict any of the *Probably would NOT happen*, *Definitely would NOT happen*, or *Refused* responses.

Table 6: Confusion Matrix GENEV4_A and BCHIP14

	A	B	C	D	E
Definitely would happen	338	281	0	0	0
Probably would happen	172	321	0	0	0
Probably would NOT happen	33	62	0	0	0
Definitely would NOT happen	19	27	0	0	0
Refused	6	18	0	0	0

Note: A: Definitely would happen, B: Probably would happen; C: Probably would NOT happen; D: Definitely would NOT happen; E: Refused

Next, we ran a random forest model as described in our Empirical Strategy section above to see if we found different significance or could improve accuracy. This model returned a misclassification rate of 0.4698512, or about 47%. This modest improvement is visible in the confusion matrix below – we see an increase in the **number of** correct predictions of

Definitely would happen and *Refused*, but a decrease in **number of** accurate predictions of *Probably would happen*. The Mean Gini Decrease identified variables BCHIP14_C and BCHIP14_D as the most influential in the forest model.

Table 7: Confusion Matrix Random Forest GENEV4_A and BCHIP14

	A	B	C	D	E
Definitely would happen	380	236	1	0	2
Probably would happen	199	288	1	2	3
Probably would NOT happen	35	60	0	0	0
Definitely would NOT happen	20	26	0	0	0
Refused	7	9	0	0	8

Note: A: Definitely would happen, B: Probably would happen; C: Probably would NOT happen; D: Definitely would NOT happen; E: Refused

Overall, the random forest and decision tree model for predicting GENEV4_A struggled to make an accurate prediction. The decision tree was best at predicting the *Definitely would happen* category with an accuracy rate of 0.546042, and the random forest was most accurate at predicting the *Probably would happen* category with an accuracy rate of 0.680851.

GENEV4_B and BCHIP14

The sub-question GENEV4_B asks respondents how likely gene editing techniques are to help people live longer and better quality lives. We ran our initial decision tree to understand the statistically significant BCHIP14 predictor values. We see that the initial split is made on BCHIP14_A [9], with the secondary split made on BCHIP14_B [10], and the final split made on BCHIP14_C [11].

The decision tree indicates that individuals who support any of the uses of neural implants outlined in BCHIP14 are likely to believe that gene editing techniques can enhance longevity and quality of life. Interestingly, even those who express negative sentiments towards neural implants for paralyzed individuals may still believe that gene editing could

[9] Would you favor or oppose the use of computer chips implants in the brain to treat age-related decline in mental abilities?

[10] Would you favor or oppose the use of computer chips implants in the brain to allow increased movement for people who are paralyzed?

[11] Would you favor or oppose the use of computer chips implants in the brain to make it possible for thoughts in the brain to search content on the internet without typing?

extend and improve life expectancy.

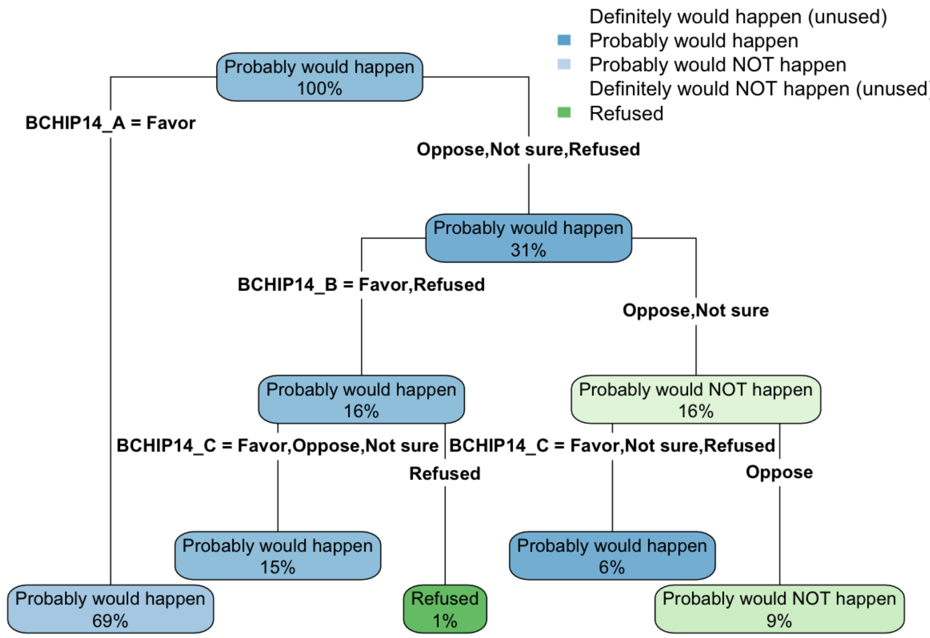

Figure 3: GENEV4_B and BCHIP14

The single decision tree yielded an error rate of 0.4424432 or approximately 44%. When reviewing the confusion matrix for the single decision tree, we can see that only the categories *Probably would happen* and the *Probably would NOT happen* had any correct predictions.

Table 8: Confusion Matrix GENEV4_B and BCHIP14

	A	B	C	D	E
Definitely would happen	0	176	4	0	0
Probably would happen	0	657	31	0	0
Probably would NOT happen	0	230	55	0	0
Definitely would NOT happen	0	58	27	0	0
Refused	0	32	7	0	0

Note: A: Definitely would happen, B: Probably would happen; C: Probably would NOT happen; D: Definitely would NOT happen; E: Refused

We then ran a random forest model as described in the Empirical strategy section above to see if we found any improvement in accuracy. The random forest model produced an error rate of 0.4361785 – almost a full percentage point of improvement in accuracy. The

Mean Gini Decrease identified BCHIP14_A as the most influential variable in the model. In reviewing the confusion matrix for the random forest, we see a decrease in the number of accurate predictions for the *Probably would happen* but an increase in the number of accurate predictions for the *Probably would NOT happen*, *Definitely would NOT happen*, and *Refused* categories.

Table 9: Confusion Matrix Random Forest GENEV4_B and BCHIP14

	A	B	C	D	E
Definitely would happen	0	175	4	0	1
Probably would happen	0	642	42	2	2
Probably would NOT happen	0	210	69	2	4
Definitely would NOT happen	0	49	33	1	2
Refused	0	24	7	0	8

Note: A: Definitely would happen, B: Probably would happen; C: Probably would NOT happen; D: Definitely would NOT happen; E: Refused

Overall, while each model produced an error rate of over 40%, the decision tree produced a higher accuracy rate for the *Probably would happen* category, while the random forest improved on the number of correct predictions and the accuracy rates for *Probably would NOT happen*, *Definitely would NOT happen*, and *Refused*. The decision tree and the random forest produced the best prediction accurate rate for the *Probably would happen* category (0.954942 accuracy for the decision tree and 0.933139 accuracy for the random forest).

GENEV4_C and BCHIP14

The sub-question GENEV4_C asks respondents how likely development of gene editing techniques are to pave the way for new medical advances that would benefit the whole society. After running our initial tree, we got stump response *Probably would happen*, which may be due to the low complexity of this particular pairing of questions. We ran the misclassification rate of the single decision tree and found it to be 0.4518403 (45.18%).

Next, we ran a random forest model to see if we could improve accuracy or find different significance. This model returned a slightly lower misclassification rate of 0.440094 (44.01%), which is more than a full percentage point of improvement in accuracy. The accompanying confusion matrix illustrated a more varied set of predictions as against the confusion matrix from single decision tree model. The Mean Gini Decrease indicated that BCHIP14_A was the most influential variable in this model.

Table 10: Confusion Matrix GENEV4_C and BCHIP14

	A	B	C	D	E
Definitely would happen	0	208	0	0	0
Probably would happen	0	700	0	0	0
Probably would NOT happen	0	249	0	0	0
Definitely would NOT happen	0	86	0	0	0
Refused	0	34	0	0	0

Note: A: Definitely would happen, B: Probably would happen; C: Probably would NOT happen; D: Definitely would NOT happen; E: Refused

Table 11: Confusion Matrix Random Forest GENEV4_C and BCHIP14

	A	B	C	D	E
Definitely would happen	0	194	4	9	1
Probably would happen	1	633	49	16	1
Probably would NOT happen	1	170	51	24	3
Definitely would NOT happen	0	50	13	23	0
Refused	0	19	5	2	8

Note: A: Definitely would happen, B: Probably would happen; C: Probably would NOT happen; D: Definitely would NOT happen; E: Refused

Overall, while each model produced an error rate of over 40%, the random forest improved on the number of correct predictions and the accuracy rates for other categories.

GENEV4_D and BCHIP14

Turning our attention to the sub-question GENEV4_D, which asks respondents how likely gene editing techniques would go too far eliminating natural differences between people in society. We ran our initial decision tree to understand the statistically significant BCHIP14 predictor values. We see that the initial split is made on BCHIP14_D and the final split made on BCHIP14_A. The decision tree indicates a more varied set of beliefs around GENEV4_D and BCHIP14. It is interesting to note that even respondents who expressed negatively towards brain chips for translating thoughts in the brain into text on a screen may still believe that gene editing would help eliminate natural differences between people in society.

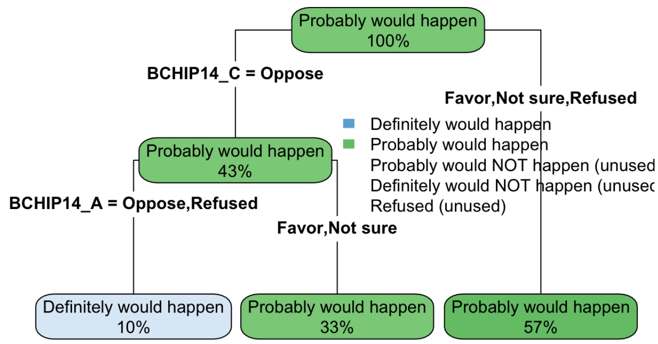

Figure 4: GENEV4_D and BCHIP14

We ran the misclassification rate of the single decision tree and found it to be 0.5364135 (53.64%). We can see from the confusion matrix that the model did not accurately predict any of the *Probably would NOT happen*, *Definitely would NOT happen*, and *Refused* responses.

Table 12: Confusion Matrix GENEV4_D and BCHIP14

	A	B	C	D	E
Definitely would happen	64	291	0	0	0
Probably would happen	35	528	0	0	0
Probably would NOT happen	16	262	0	0	0
Definitely would NOT happen	11	45	0	0	0
Refused	10	15	0	0	0

Note: A: Definitely would happen, B: Probably would happen; C: Probably would NOT happen; D: Definitely would NOT happen; E: Refused

Next, we ran a random forest model to see if we could improve accuracy or find different significance. This model returned a slightly lower misclassification rate of 0.5301488 (53.01%), denoting a minor improvement in predictive performance over the single decision tree model. The accompanying confusion matrix illustrated a more varied set of predictions as it acknowledged categories (*Probably would NOT happen, Definitely would NOT happen, or Refused responses*) more effectively than the decision tree model. The Mean Decrease Gini of this model shows the importance of BCHIP14_D, BCHIP14_C, and BCHIP14_A, which is mostly in alignment with the variables identified by the decision tree above.

Table 13: Confusion Matrix Random Forest GENEV4_D and BCHIP14

	A	B	C	D	E
Definitely would happen	84	269	0	1	1
Probably would happen	50	508	1	1	3
Probably would NOT happen	16	260	1	0	1
Definitely would NOT happen	12	43	1	0	0
Refused	1	17	0	0	7

Note: A: Definitely would happen, B: Probably would happen; C: Probably would NOT happen; D: Definitely would NOT happen; E: Refused

In sum, the random forest model offered a nuanced perspective by improving the distribution of predictions across different categories. However, both models had error rates exceeding 50%, highlighting the challenges in predicting public attitudes.

Ability of neural implants and gene editing to predict scientific attitudes

As a supplemental analysis, we wanted to understand if attitudes towards neural implants or gene editing could be used to predict an individual's overall attitudes towards science. We decided to use all of the BCHIP and GENEV questions used in our previous analysis as predictor variables, and the question SC1[12] from the ATP survey as our dependent variable. We ran 4 separate models – one with each GENEV or BCHIP question as predictors for the SC1 dependent variable.

The first pairing, BCHIP3, and SC1, produced a "stump" of a decision tree, indicating that no matter an individual's response to the BCHIP3 question (an individual's preference to have a neural implant for increased cognition), they would likely agree that science had a mostly positive effect on society. The decision tree and the random forest models yielded a misclassification rate of 0.2913078. As we ensured that our model was properly tuned by checking our complexity parameter, we suggest that this finding may be due to the low complexity of this particular pairing of questions.

[12]Overall, would you say science has had a mostly positive effect on our society or a mostly negative effect on our society? a. Mostly positive, b. Mostly negative, c. Equal positive and negative effects.

The next pairing of BCHIP14 and SC1 examines whether we can use an individual's attitude towards different uses of neural implants could be used to predict their attitudes towards science. By and large, the decision tree (see Appendix A, Figure 1) indicates that most combinations of the BCHIP14 question responses lead to individuals regarding science as having a mostly positive influence on society. The only exception to this was in the case of:

- an opposition or refusal to answer a question related to the use of neural chips to treat age-related decline in aging patients (BCHIP14_A),
- an opposition or refusal to answer a question related to the use of neural chips to translate thoughts in the brain, without speaking, into text on a screen (BCHIP14_D),
- ambiguity in opinion to a question related make it possible for thoughts in the brain to search content on the internet without typing (BCHIP14_C).

This combination of opinions led to the algorithm predicting a response of *Equal positive and negative effects*.

The initial decision tree had a misclassification rate of 0.2928739, and the random forest had a misclassification rate of 0.2866092. The random forest Mean Decrease Gini showed BCHIP_A remained the most influential variable, but BCHIP_B exerted the second most influence, and BCHIP_D was third most influential. The confusion matrix for the random forest model (see Appendix A, Table 1) shows that the random forest was most successful at predicting *Mostly positive*, with over 99% of those values correctly predicted.

Shifting our views to the gene editing questions, we examined the predictive ability of an individual's response to GENEV3 (If gene editing to greatly reduce a baby's risk of developing serious diseases or health conditions over their lifetime were available, is this something you would want?). Again, we observe a "stump" of all GENEV3 variables leading to a *Mostly positive* prediction for SC1. The decision tree and random forest model yielded the same misclassification rate (0.2913078). Again, we determined that our model was tuned correctly, leading us again to believe that these results were caused by a lack of complexity in this pairing.

Finally, we assessed the predictive power of respondents' answers to GENEV4 (which presents morally framed perspectives on gene editing) concerning their responses to SC1. The initial decision tree (see Appendix A, Figure 2) underscores the significance of sub-question B (the belief that gene-editing techniques would extend lifespan and enhance its quality) and sub-question C (the belief that gene editing could usher in new medical breakthroughs) in eliciting positive responses for SC1. This decision tree achieved a misclassification rate of 0.275646, indicating that it's the most accurate predictor of SC1 among all our test sets. The Mean Decrease Gini for the random forest model also found the same influence of the BCHIP_B and BCHIP_C variables, and yielded the same misclassification rate upon the initial run and retuning, leading us to believe that perhaps the initial decision tree is effectively modeling the data, and the random forest's additional analysis was unneeded.

Impact of Demographics on Gene Editing Attitudes

As an additional supplement to our main analysis, we returned to the demographics highlighted in our literature review, particularly the discrepancy between the findings of Robillard et al. (2014) and Scheufele et al. (2017) regarding the influence of religious affiliation on attitudes toward genetic editing. We aimed to explore whether specific characteristics could predict an individual's stance on gene editing.

We selected the variables SC1[13], `F_AGECAT`[14], `F_EDUCCAT`[15], `F_RELIMP` [16], `F_RELIGCAT1` [17],`F_GENDER`[18], and `F_CREGION`[19] for our supplementary analysis, and thereby extended our analysis beyond religious affiliations.

[13]Opinions on scientific advances
[14]Age of respondent
[15]Level of educational attainment
[16]How important is religion to respondent
[17]Religious affiliation
[18]Gender of the respondent
[19]What region of the US

In examining the impact of demographic variables on the perception of scientific advances (SC1), our decision tree model stumps to Mostly positive view. The misclassification rate of 28.11% highlights a limitation in predicting the variability of individuals' opinions on scientific advances using the given demographic factors.

The decision tree model reveals that the importance of religion plays a role in shaping opinions on gene editing for babies. Individuals who find religion to be 'Very important' are predicted to reject gene editing, with 41% inclined to strongly oppose it. Conversely, for those who consider religion to be less central (*Somewhat important* to *Not at all important*), there is a 59% predicted probability of favoring gene editing. The error rate of over 63% indicates significant misclassification, suggesting a complex relationship between religious importance and gene editing attitudes that the model may not fully capture. This complexity could stem from varying interpretations of religious teachings, personal beliefs, or other unmeasured factors.

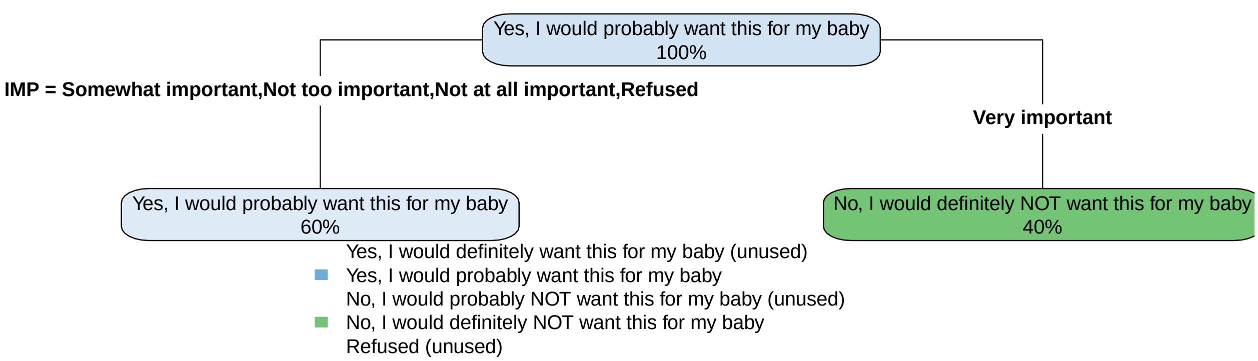

Figure 5: Importance of Religion and GENEV3

The decision tree analysis considering both religious affiliation and geographical region as predictors for attitudes towards gene editing for babies stumps to "Yes, I would probably want this for my baby" category. However, a high error rate of 63.43% for religious affiliation and 63.19% for geographical regions suggests a complex underlying reality which might influence opinions on gene editing in varied and nuanced ways that the model does not capture due to its oversimplification. This can also be reflective of the diverse spectrum of beliefs within religious categories, making a single decision tree inadequate to model such intricacies accurately.

The decision tree constructed to assess the influence of education level on attitudes towards gene editing for babies (GENEV3) indicates a nuanced view among respondents. It shows that college graduates favor gene editing for babies, while those with some colleges are evenly split. Notably, 18% of respondents with high school education or less are firmly against it. The error rate of 63.35% suggests diverse opinions on gene editing across educational levels, highlighting the model's difficulty in predicting attitudes with education as the sole factor.

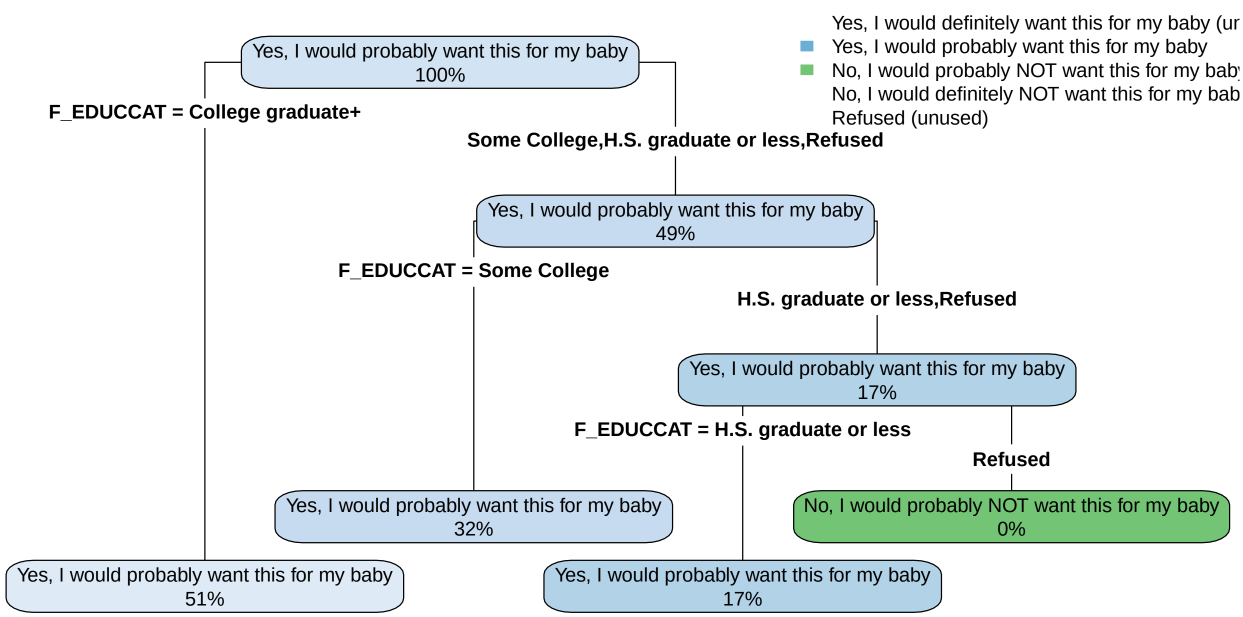

Figure 6: Educational Attainment and GENEV3

The decision tree analysis examining the relationship between gender and attitudes towards gene editing for babies suggests a differentiated impact based on gender. The scenario is complex for female respondents and others, where the decision tree reveals a majority, but not a consensus, leaning towards acceptance of gene editing, with 55% probably favoring the technology. The error rate of 63.19% indicates a significant level of misclassification, implying that while gender may influence attitudes toward gene editing, it is not a clear-cut predictor.

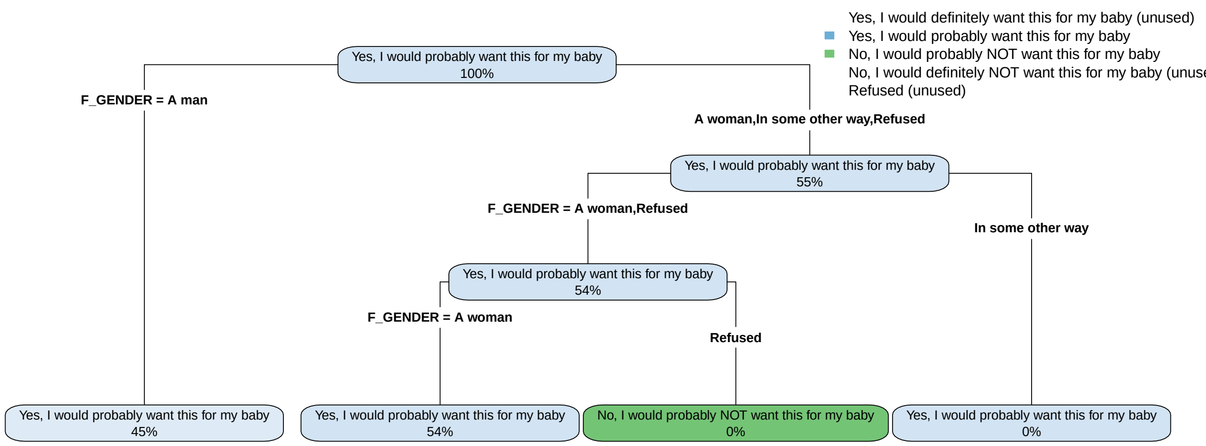

Figure 7: Gender and GENEV3

Conclusion

Our analysis underscores the intricate relationship between personal and moralistic views on artificial intelligence applications related to neural chip implants, gene editing, and overall attitudes towards science. Attitudes on personal-use applications did not exhibit a significant influence on broader science opinions. Instead, moralistic considerations and potential applications showed a stronger effect. For instance, support for neural implants to mitigate age-related decline and the belief in gene editing's potential to extend life and improve its quality were indicative of a positive view of science's impact on society. The misclassification rates observed were relatively modest for these dimensions, hovering around 28-29%, suggesting a reasonable level of accuracy in our models. Conversely, BCHIP indicators did not prove to be robust predictors of attitudes towards GENEV questions, with an average misclassification rate of about 49%. This contrast highlights the complex and sometimes contradictory nature of public attitudes towards neural chips and embryonic gene editing.

Our comparative analysis between logistic and linear regression models further emphasizes these findings. Logistic regression demonstrated a consistent influence of variables across different model specifications, indicating stable underlying beliefs, whereas linear regression showed a variable impact, suggesting the effects might be contingent on additional, unmeasured factors.

The divergence between explanatory models and predictive modeling also revealed the nuanced landscape of public perceptions. Predictive modeling provided a more granular understanding of the factors at play, suggesting that positive attitudes towards neural implants and gene editing may be harbingers of a broader acceptance of scientific advancements.

Our study is limited by the selection of demographic variables and the range of questions analyzed from the BCHIP and GENEV sections. Potential influences from unexplored demographic variables such as race or ethnicity may provide further insights. Additionally, the high misclassification rates, particularly evident in predictions from BCHIP indicators, point to the need for more nuanced modeling techniques to capture the complexities of public opinions on gene editing and neural implants more accurately.

In sum, the analysis suggests that while individual views on neural chip implants and gene editing are complex and multifaceted, there is a discernible pattern where positive sentiment towards certain applications can signal a general positive stance towards the role of science in society. This insight is vital for research and policy making, as it indicates the areas where public engagement efforts might be most effectively focused.

References

Code for this project can be found here: https://tinyurl.com/43rn4k7a

and here: https://github.com/PixelCristina/DMProject/blob/main/LinearregressionV2.R

Appendix A can be found here: https://tinyurl.com/2n5bfn8s

Dafoe, Allan, Baobao Zhang, and Devin Caughey. 2015. Confounding in Survey Experiments. *Annual meeting of The Society for Political Methodology, University of Rochester, July 23, 2015*.

Lahr, Jacob, Christina Schwartz, Bernhard Heimbach, Ad Aertsen, Jörn Rickert, and Tonio Ball. 2015. Invasive brain–machine interfaces: a survey of paralyzed patients' attitudes, knowledge and methods of information retrieval. *12*(4), 043001. Publisher: IOP Publishing.

Morrison, Michael and Stevienna de Saille. 2019. CRISPR in context: towards a socially responsible debate on embryo editing. *5*(1), 1–9. Number: 1 Publisher: Palgrave.

Reinares-Lara, Eva, Cristina Olarte-Pascual, and Jorge Pelegrín-Borondo. 2018. Do you want to be a cyborg? The moderating effect of ethics on neural implant acceptance. *85*, 43–53.

Robillard, Julie M., Dylan Roskams-Edris, Boris Kuzeljevic, and Judy Illes. 2014. Prevailing public perceptions of the ethics of gene therapy. *25*(8), 740–746.

Scheufele, Dietram A., Michael A. Xenos, Emily L. Howell, Kathleen M. Rose, Dominique Brossard, and Bruce W. Hardy. 2017. U.s. attitudes on human genome editing. *357*(6351), 553–554. Publisher: American Association for the Advancement of Science.

Tyson, Cary Funk, Monica Anderson, and Lee Rainie Alec. 2022. AI and Human Enhancement: Americans' Openness Is Tempered by a Range of Concerns.