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# Analyzing the American Public's Views on the Uses of Modern Neural Implants

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## ABSTRACT

Researchers are currently developing neural implants, specifically brain-computer interfaces (BCIs), to help people move, communicate, and think. BCIs work by recording neural activity through a surgically implanted device, and then transferring that information to a computer that can react to help the person perform a specific ability, such as typing words thought by the implantee. BCIs have several potential applications in the medical field and in the field of human enhancement, but there is not a significant body of research regarding how people view the different uses. This study aimed to figure out what kinds of BCI uses are socially acceptable, and if any age groups are significantly more or less trusting of certain uses. The data was collected through a digital survey and in the end, there were 37 responses. The results showed that the tested population was generally accepting of BCIs when they are used to treat physical conditions, but not supportive of BCIs used to treat mental conditions or enhance human capabilities. Additionally, there was no correlation between age and views on BCIs.

## Introduction

Right now, researchers are developing neural implants to help people move, communicate, and even think. Very few people know about neural implants, but once the public knows about the potential of this rising technology, peoples 'views will most likely influence how neural implants change human interactions with technology. Neural implants are devices that doctors or robots surgically implant into the brain to interact with neurons and help the neurons perform a specific function (McDermott-Murphy, 2019). Some neural implants are already widely used as a medical treatment, including cochlear implants and deep brain stimulation. More than one million people around the world use cochlear implants as a treatment for sensorineural deafness; the implants transmit auditory information directly to the auditory nerve inside the brain (Zeng, 2022). More than 160,000 patients use deep brain stimulation to treat several neurological disorders, most commonly Parkinson's disease. The implant stimulates the brain by sending electrical pulses through a set of implanted electrodes, which can lessen the symptoms of the disorder in the patient (Lozano et al., 2019). Both of the above treatments have become widely accepted and successful treatment methods on a global scale, which has paved the way for further developments in the field of neural implant technology.

At present, neural implants are being tested as treatment options for individuals suffering from severe physical conditions, like speech impairments and paralysis (Saha et al., 2021). These neural implants, more specifically known as brain-computer interfaces (BCIs), operate differently from previous options because they do more than simply add stimuli to the brain. Instead, BCIs record the brain's neural activity, process that information using a computer system, and then react appropriately, which essentially means they facilitate uninterrupted communication between the brain and a computer without any requirements for physical movement (Kawala-Sterniuk et al., 2021). However, the existence of BCIs raises ethical questions about what this technology should be used for, both in the medical field and beyond.

## Literature Review

Initial BCI patients have already seen some medical success with BCIs. For example, Ann Johnson, who lost her ability to speak clearly after a stroke, underwent a surgery which implanted a device that could record her neural activity. As Johnson attempted to speak, the implant transmitted the corresponding signals to a computer, which translated them into text and sounds (Howard, 2023). The BCI was able to interpret what Johnson wanted to say at 60 to 70 words per minute, which is much closer to average conversational speeds than previous devices, which tracked eye movements or utilized other external data collection methods and were limited to around 18 words per minute (Howard, 2023). The significant increase in efficiency shown in BCIs could have the potential to completely change the medical field for treating previously permanent conditions.

Noland Arbaugh also received a BCI, one that served an entirely different purpose. Arbaugh is quadriplegic, paralyzed from the shoulders down, and received a BCI in January 2024 to increase his accessibility; it gave him the ability to control a computer mouse and interact with computer applications solely through his thoughts (Neuralink, 2024). His BCI was developed by a startup called Neuralink, one of the organizations currently making steady progress in neural implant research. Neuralink's founder Elon Musk plans to use Neuralink and its interaction with the spinal cord and central nervous system to cure paralysis, blindness, and potentially several other chronic conditions (Musk, 2019). In May 2023, Neuralink was approved for its first in-human clinical trials to test its implant, and Arbaugh was the first patient. Arbaugh explained that, after getting used to having it, playing games on a computer became intuitive because he could just imagine what he wanted the computer to do, and then the computer would do it (Neuralink, 2024). Images 1 and 2, shown below, depict the components of Neuralink's BCI and Noland Arbaugh as he uses his implant, respectively.

**Figure 1.** Exploded View of Neuralink Implant (Neuralink, 2024)

**Figure 2.** Noland Arbaugh Using Neuralink Implants to Play Chess (Griffin, 2024)

In the coming years, Neuralink is planning to expand further than treating chronic conditions and eventually push the boundaries of human capability, and it is not alone. A team of researchers analyzed the potential of neuroscience technologies in 2022 and explained that once companies like Neuralink are able to confidently use their BCIs as a consumer product, the technology will move on to the world of brain augmentation and add overlays to our existing sensory inputs (Jangwan et al., 2022). Essentially, the implant would allow the brain to artificially sense additional information through a computer chip. Stanford University research scientist Francis Willett and his team further elaborated that future BCIs with such advanced capabilities would allow people to use technology directly through our heads for actions as complicated as accessing the internet or digital maps (Willett et al., 2023). People currently rely on handheld or desktop devices for those actions, but if the neural implant industry reaches the point where it develops consumer grade products, there is a potential for BCIs to completely reshape peoples' current relationships with technology and the internet. What remains to be seen, however, is what sort of market there is for consumer BCIs as they work towards furthering the technology.

## Public Views on BCIs

Because BCI technology is so new, there is not yet a large body of research on the science of public perception and neurotechnology. A few studies have analyzed differences of opinion by demographic on similar technologies (Budin-Ljøsne et al., 2020; Carver et al., 2022). A group of international scientists specializing in areas ranging from genetics and bioinformatics to psychology published their methodology for analyzing how different groups of people (divided based on age, gender, education, and home country) view the importance of learning about and understanding brain health (Budin-Ljøsne et al., 2020). The group used a survey, distributed to 76 countries, to locate patterns of thinking of different demographics on the subject. A similar survey study looked at how willing or unwilling participants are to take a test to evaluate their brain health, and the digital design of the survey allowed it to be easily distributed to diverse demographics. The results showed that there was a heavy public interest in taking a brain heath test, despite the risk that it could reveal an untreatable disease (Carver et al., 2022). Both of the aforementioned studies focused on the people's views on brain health and diagnosis of brain-related issues, but did not delve into treatments for brain-related conditions and treatments like BCIs.

After understanding how people value monitoring and learning about the brain, it is important to evaluate how the public views BCIs because of the relationship they have with the brain's functioning ability. One study from the Pew Research Center found that there is a general dislike for devices that directly interact with the human body, a belief that grows stronger when the device interacts with the brain (Funk et al., 2016). The anti-BCI views appear to have remained consistent over the following years. A 2022 survey of over 10,000 US adults found that 78% of respondents would not want an implant that could improve their brain's ability to process information (Rainie et al., 2022). Both research groups identified that people do not trust BCIs and suggested the potential reason for this distrust is the lack of knowledge about the intentions of neural implant developers (Funk et al., 2016; Rainie et al., 2022).

### Purpose

What is currently unknown is how comfortable the public is with neural implants such as Neuralink, both as a medical treatment and as an enhancement technology, which may help predict the direction of further advances in this technology. It is also important for researchers to understand which individuals are more trusting of the technology and which are more likely to avoid it because public opinions could be a driving factor in further advances of BCI technology. There has not yet been significant research into how the public views the various different uses of BCIs because previous studies have looked at BCIs from a more general perspective instead of the diverse potential of the technology. It also has not analyzed if any demographic groups are more likely to have certain beliefs on BCIs, either for or against them. The goal of this study is to fill the gap in current literature and answer the following question: To what extent do people in the United States currently support the different potential uses of brain-computer interfaces? Throughout this study, the validity of two assumptions will be tested to answer the research question: (1) The American public is going to be more open to BCIs that are used for medical purposes than to ones that enhance the brain's current capabilities; (2) Younger generations, seeing as they have had significant access to technology all throughout their lives, are going to be more trusting of BCIs than older generations, who have had technology develop during their lives.

## Methods

This quantitative study of American participants used the self-report survey method to measure public opinions on BCI uses for several reasons. A survey is easily distributed and standardized, so it can be taken by a wide range of demographics, which is crucial for the success of this study. It is also the least invasive option for participants and simplifies the data collection process because surveys can easily be designed to prevent incomplete or unusable responses. The U.S. Bureau of Labor Statistics uses the standardized survey method, by way of the U.S. Census, because of its effectiveness in identifying individual traits of various groups in a large and diverse population (BLS, 2018). This study follows similar reasoning; all participants in this study received a standardized survey to keep the delivery of the survey impartial, thus reducing bias on the part of the researcher. The survey method is commonly used to measure public opinions on brain health and neurotechnology, as found during the literature review, because of the ease of use and the quantifiable results that can be reviewed objectively (Budin-Ljøsne et al., 2020; Carver et al., 2022; Funk et al., 2016; Rainie et al., 2022).

This study took into account the flaws in self-report measures of risk preference in order to maintain the credibility of the results. Self-report studies sometimes raise questions about the generalizability results in comparison to other data collection methods (Mata et al., 2018). The main concern comes from two factors: the self-report survey is not always able to accurately represent opinions because of the situation and nuance of individual beliefs, and the population taking the survey may not be representative of the general population (Friedman et al. 2014). Essentially, it is impossible to guarantee participant honesty, which can unintentionally skew the resulting data. It is also difficult to survey a generalizable population because willingness to take the survey cannot be guaranteed, so the people who are willing to participate generally will not be able to represent those who abstain.

Despite the risks, previous social science researchers, especially those who intend to analyze demographic groups, have chosen to collect data using the survey method. Measurable demographics are relatively limitless in a survey, so this method can even thoroughly analyze how risk preference changes with age (Dohmen et al. 2017). One 2015 study, which collected surveys from teens to determine the extent of the issue that is problematic internet usage, found that the self-report survey method can be effective for the collection of opinions across a large population, as long as its limitations are properly accounted for (Breslau et al., 2015). In order for the survey method to better represent a population, it should diversify the survey distribution locations. If all the surveys are distributed on a college campus, for example, the results will not be reliable enough to be generalized to a population greater than the campus itself. This survey was partially distributed using social media accounts of users who have lived in several U.S. cities and are connected with people across the country, so that choice should have increased the diversity of the sample population. The survey method was also a practical choice for a researcher who is a high school student with limited resources and time constraints. When the risks of a potentially misrepresented population and potentially misinterpreted survey questions were accounted for, it became clear that the survey method was a reasonable choice for this study.

## Population

The specific population tested in the study included Americans over the age of eleven who were willing to participate. The survey included an evaluation of the risk preferences of participants in order to show individual comfort levels with BCIs. Risk preference is defined in slightly different ways across different fields, but for the purposes of this study, risk preference is defined as the varying tendency to participate in activities that possess both a reward and a potential risk (Steinberg, 2013). Risk preferences that are measured in the form of a survey are quantifiable, which allows them to be analyzed for correlations and patterns. In order to conclude on how different age groups vary in their risk preferences in regards to BCI uses, this study set a goal of at least 30 responses. All participants received the same standard set of questions as a Google Form, a suitable application for creating the self-report survey due to the simplicity of digital distribution. Google Forms are accessible for anyone with an internet connection, are simple to design and fill out, and ensure the anonymity of participants, which was kept throughout the research process. The results were evaluated mainly as a whole sample population, and then separated based on age demographic in order to address this study’s second assumption.

## Survey Design

The survey contained four sections: background information, consent forms, demographic information, and opinion information. The background information was designed to give participants a basic understanding of neural implant technology, while avoiding any biased language that could sway opinions for or against BCI technology. It was necessary to include this section in the survey because about 92% of Americans have little to no knowledge about neural implants (Funk et al., 2016). It allows participants to more accurately report their opinions throughout the rest of the survey. The second section of the survey asked participants to sign a consent form to officially agree to partake in the study, ensuring that there would be no ethical boundaries breached throughout the data collection process (NIH, 2016).

The third section, demographic information, asked participants to accurately mark their year of birth, gender, education level, and prior familiarity with neural implants. This section allowed the results to be sorted and analyzed from more specific perspectives than just the general population during the analysis. This information was kept anonymous, which was made clear to all participants, in order to uphold the ethical guidelines required for a legitimate conclusion recommended by the National Institutes of Health Clinical Center (NIH, 2016). Keeping participants anonymous protects results from researcher bias, the misinterpretation of results during analysis due to the potential to obtain additional knowledge about participants, and social desirability bias, the phenomenon where participants respond to questions differently when their responses can be connected back to them in an attempt to fit more acceptable social norms (Dougherty, 2021; Pannucci & Wilkins, 2010). By establishing that participants will not be identifiable, the survey most likely increased the likelihood the participants answered the questions honestly throughout the rest of the survey.

The final section of the survey contained questions that measured the risk preferences and opinions of each participant. It asked participants to plot their answer on a Likert scale, a long-utilized scale for measuring opinions and attitudes towards a certain subject (Salkind, 2010). This study used a variation on the Likert scale to reduce confusion for participants as they read each question. To do so, each end of the five-point scale contained an indicator of the opinion it agrees with, with the opposite indicator representing a contrasting opinion. For example, two of the questions contained the indicators "Not safe at all" next to the low end of the scale (1) and "Completely safe" next to the high end (5). The indicators were tailored to the context of each question, and were designed to keep the low end of the scale representing views of a lack of safety and trust in neural implants; the high end of the scale generally represented total safety and confidence in the given neural implant use.

To reduce the differences in possible interpretations of each survey question, it is best to test the best question formats that yield the most clear results. The National Library of Medicine published research finding that the best route for creating an effective data collection method is to complete a pilot study, which allows the researcher to evaluate any flaws in their method choices (Hassan et al., 2006). This study went through with a pilot study process and it was a highly informative step in the research process because it identified several issues with the original survey questions and content. The results of the pilot study and verbal feedback from pilot participants caused changes to the wording of the background information section, the demographic information section, and the opinion question section. The changes were mainly reductions in confusing wording, but they also included asking participants for their year of birth instead of the generation they are a part of, which supported more specific comparisons, and expanding on the different medical uses of BCIs in order to better differentiate among BCI uses.

## Results & Analysis

By the end of the data collection period, there were 37 responses to the survey. About 68% of participants were adults and about 32% of participants over age eleven who took the survey with consent from a legal parent or guardian. Three primary areas of the results were analyzed: the views people had regarding the different medical uses of BCIs, the comparison between views people had about medical versus enhancement BCIs, and if there is any correlation between age and BCI views.

First, the researcher compared the results from questions 3, 4, 5, and 6 to determine what medical uses of BCIs are trusted the most. Based on graphs 1, 2, 3, and 4 (shown below), there is heavy support for BCIs that treat speech impairments, paralysis, epilepsy, Parkinson's disease, and depression, and (lesser) support for BCIs that treat type 2 diabetes and heart disease. There was one outlier when looking at the medical uses that neural implants could have: stress reduction. As shown by graph 4, participants were notably less accepting of neural implants for stress. This result helps to answer the research question by suggesting that the public supports medical BCIs that are used to treat severe physical conditions, but not conditions involving mental health.

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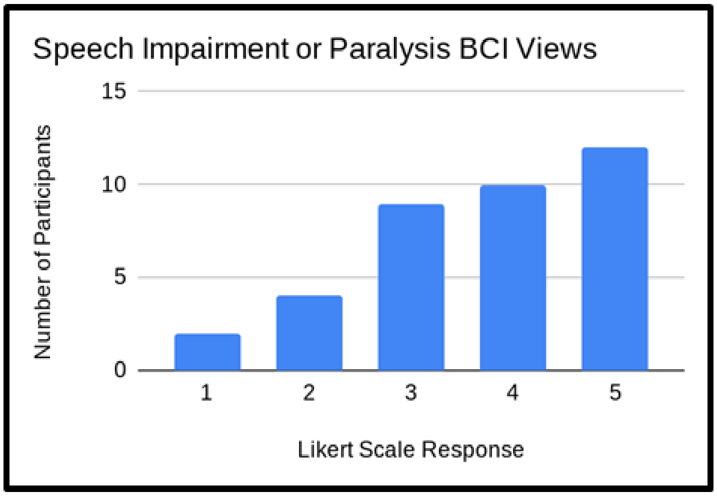



**Figure 3.**

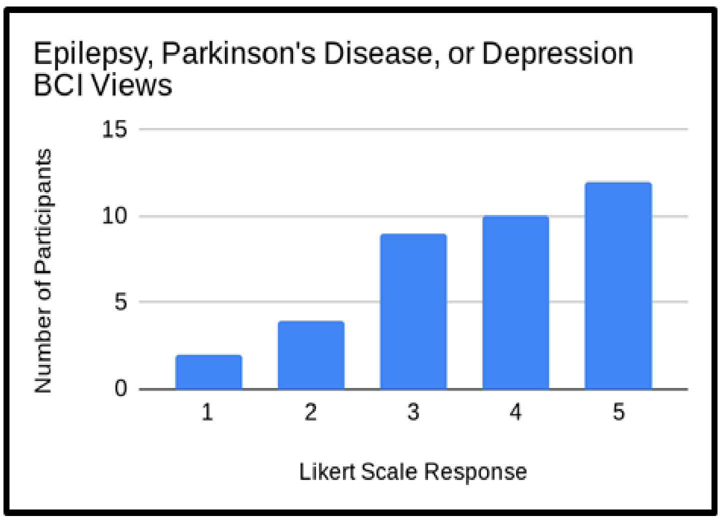
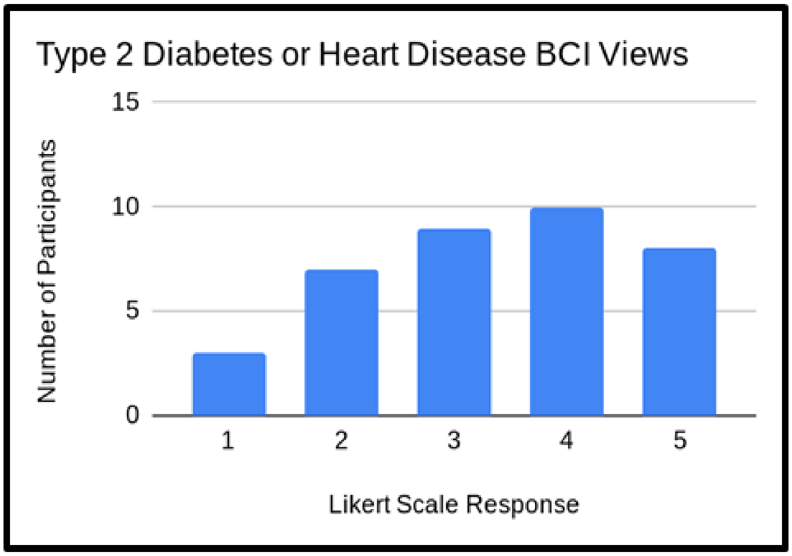



**Figure 4.**

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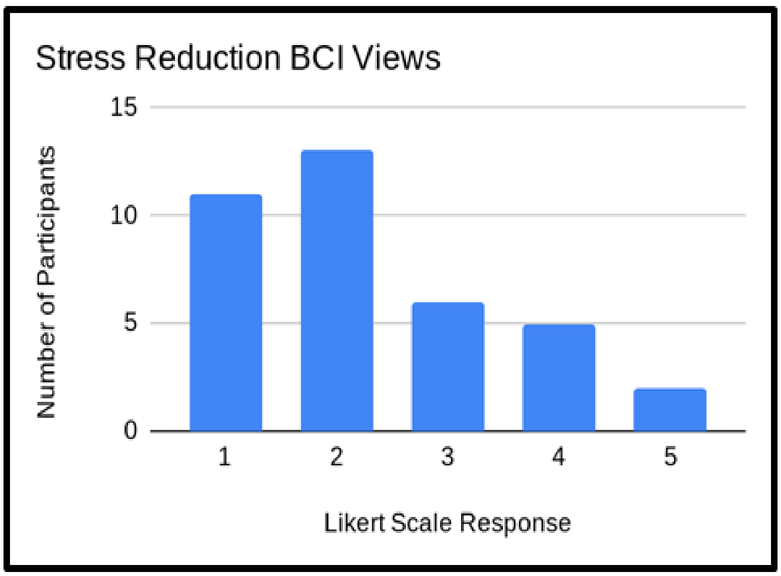


**Figure 6.**

Next, the researcher compared the results of questions 7 and 10 to determine if views on medical BCIs as a whole are different from those regarding enhancement BCIs. Based on graphs 5 and 6 (shown below), there appear to be opposite views regarding the two BCI categories, with support for medical BCIs and opposition towards enhancement BCIs. Question 10 specifically asked about enhancement BCIs with internet access, a likely ability of enhancement BCIs (Jangwan et al. 2022). The results from questions 7 and 10 show that only 8.1% of participants are against the medical BCIs, compared to 51.3% of participants that are against the enhancement BCIs. There is a significant difference between the two numbers, indicating that people are much more likely to be comfortable with medical neural implants if they become more available for wide-spread use; they are likely to avoid neural implants that are being used for human enhancement. This result confirms the first assumption by showing that there is greater public trust in medical BCIs than enhancement BCIs.

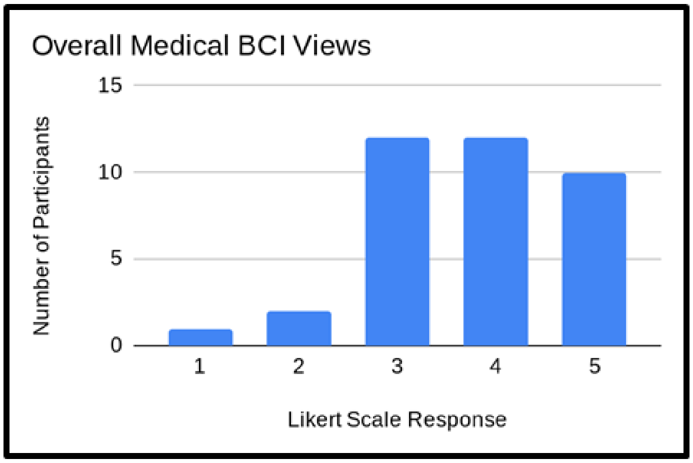


**Figure 7.**

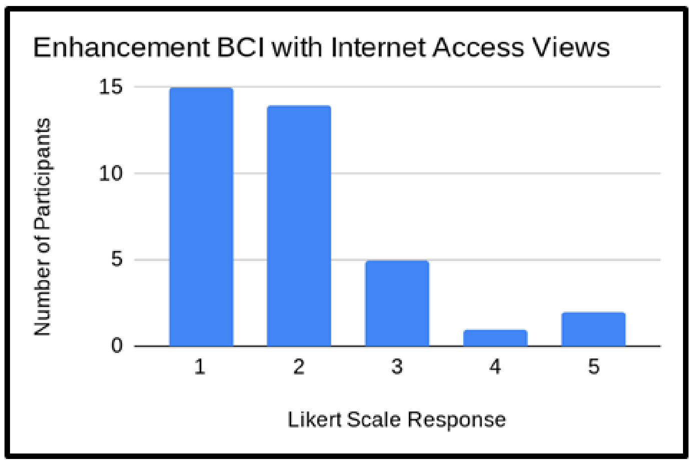


**Figure 8.**

Finally, the researcher compared the results of questions 7 and 10 again, but instead organized each response in order of birth year to determine if there is a correlation between trust in BCIs and age. Before analyzing the results, it is important to note the preconception that the public has regarding age in relation to BCI views. According to this survey, 87% of participants believe younger generations are more trusting of neural implants, a view that is consistent with the second assumption of this study. The preconception is likely a result of the different experiences that younger and older generations have had with technology throughout their lives, where younger generations grew up with technology, and older generations witnessed dramatic growth of technology.

Based on graphs 7 and 8 (shown below), there is no observable or statistically significant relationship between age and trust, which is contrary to both popular belief and the second assumption. For both graph 7 and graph 8, there is no trend line that can suggest that any age group is more or less supportive of BCIs. Average responses for medical BCIs are positive and average responses for enhancement BCIs are negative, with the outliers in each graph showing no consistent connection to a particular age range. The evidence suggests that age does not play a role in the level of trust a person has regarding a neural implant, no matter what the implant is used for. This result is interesting because the *Oxford Academic* published research that discovered that older generations are less likely to take risks, and generally are the most cautious after the age of 65 (Dohmen et al. 2017). Getting a BCI implant would qualify as a risk, so the results show in graphs 7 and 8 do not follow previous research on generational beliefs.

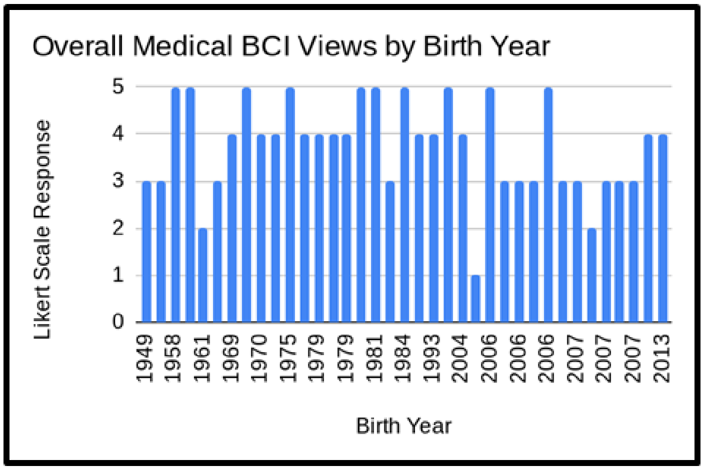


**Figure 9.**

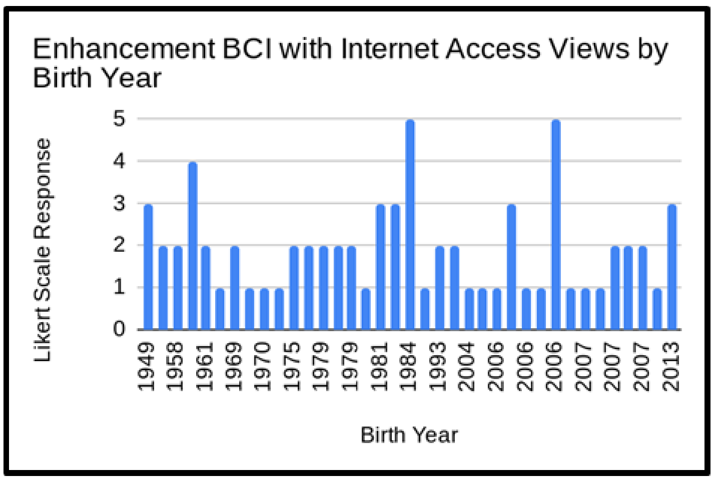


**Figure 10.**

## Conclusion

The results suggest that people are generally willing to use neural implants as a treatment option for chronic physical conditions, but significantly less likely to use one for mental health or human enhancement. This is intriguing because the views regarding medical BCIs varied depending on the use, which expands on the first assumption of this study which generalized all of the medical uses into one medical category; the first assumption did not account for differences of opinion within the category of medical BCI uses. Previous research was only able to establish public opinions on a BCI that improves the brain's processing abilities, but graphs 1, 2, 3, and 4 expanded on the multitude of medical applications of BCI technology by suggesting that the public possesses varying views on medical BCIs, depending on their intended purpose.

Both stress BCIs and enhancement BCIs would involve allowing a piece of technology to directly impact human thought processes, which is different from the socially acceptable medical BCIs that treat physical conditions. The concept of a BCI that interacts with the cognitive side of the brain instead of the physical side could be why people are less trusting of those uses. Another potential explanation for such a dramatic decrease in support for stress and enhancement BCIs could also be that the current background information available about how neural implants actually assist people is only able to show proof of specific medical BCIs working successfully. There are real examples of BCIs being successful options as medical treatments, like the one implanted in Ann Johnson (Howard, 2023). However, enhancement and stress BCIs are currently still theoretical, so there is no proof for the public to use while forming their opinions. It was noted in the background information section of the survey that a neural implant has been successfully used as a treatment for someone with a speech impairment that was much more efficient than the previously best treatment options. If people were able to see success in human enhancement methods, they might become more open to them due to the mere exposure effect, a phenomenon where people are more open to supporting something when they have more information about that thing (Yagi & Inoue, 2018).

The results of this study suggest the second assumption was entirely incorrect because of the results on graphs 7 and 8. Both the participants' preconceptions and the second assumption were incorrect because there was no statistically significant correlation between age and views on BCIs. The lack of correlation appeared consistent between both medical and enhancement applications of BCIs. Because there is no correlation, the tested population appears to possess the same average views of different BCI uses. However, this population does not believe that this result is true because the large majority of survey respondents stated younger generations would be more supportive of BCIs.

## Future Directions

There are several ways that future researchers could further the results of this study. The first is by replicating the survey regularly. Transforming the survey into a longitudinal study, a study that monitors the same population over an extended period of time, could allow researchers to measure how views on different BCI uses shift as the technology continues to develop. Future surveys could also provide examples of the successes of each kind of BCI that has been developed and measure if the presence of real BCI success has any relationship with the beliefs about that BCI’s use. A longitudinal study would be able to monitor for changes in opinions as the BCI developments take place. This method would also make it possible for future researchers to study if opinions regarding BCIs change due to the public becoming more aware of BCI technology. An increased public awareness of BCIs could facilitate the bandwagon effect, where people conform to the beliefs and decisions of a larger or louder population (Unkelbach, 2023). The bandwagon effect would be easily observable in a longitudinal study.

This study was able to analyze the (lack of) correlation between age and beliefs regarding BCIs, but it would be beneficial for other researchers to study any potential correlations between BCI views and other demographic groups, like gender, religion, race/cultural background, education level, economic standing, or even personality traits. Some people with certain personality traits, for example, often possess similar views on a specific subject; their personality traits could cause them to be more or less likely to support BCIs (Josef et al., 2016). This study was not able to explore other demographics ’views because of the small sample size this survey ended up with. The demographic information section collected some demographic information beyond just age, but the other demographics could not be analyzed because there was not a large enough population range to analyze. Other demographic characteristics like race/cultural background, personality traits, religion, and economic standing were not collected during the survey because the focus was on the potential age correlation and the views of the general public, so this study was unable to analyze them. Future researchers could collect usable data for each of these categories by following the format of the background information questions in this survey. A more detailed collection of demographic data would allow future researchers to identify any possible correlations between demographic factors and views on each use of BCIs.

## Limitations

There were some limitations to the conclusions made in this study, with the most significant one being that the sample size, at only 37, might disproportionately represent certain areas in the United States due to differences in cultural backgrounds and regional beliefs. The survey did not inquire about the race of each participant, so there is no way to be certain if it accurately represents the population. With that being said, the distribution method for this survey could also alter the results because they are likely to disproportionately represent the region the researcher is located in. Participants were not picked using random sampling, which is a requirement for the results of the study to be generalizable (Mata et al., 2018). The survey in this study has a similar limitation in sampling as Budin-Ljøsne and collaborators in that both used convenience sampling, where participants are found based on the channels the researcher has access to, which could unintentionally skew the results because the people around the researcher are not accurate representations of the greater population of the United States (Budin-Ljøsne et al., 2020). One other possible source of inaccuracy stems from the data collection tool itself. Although the researcher attempted to streamline the survey to reduce any confusion for participants as they marked their opinions, it is nearly impossible to make a quantifiable measure of opinions because opinions contain levels of nuance that cannot be fully represented on a five point scale (Friedman et al. 2014).

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