Thesis Project Portfolio

Adaptive Humanoid Robots and Pediatrics: NAO Robots
(Technical Report)

Designer Babies and the Equality Threatened in Society

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Meghna Singh
Fall, 2022
Department of Computer Science

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Sociotechnical Synthesis

An Exploration of Medical Technology and the Ethics they Disturb

Though not directly correlated, my technical and STS deliverable both relate to medical technologies and the ethical issues they impose. This past year the University of Virginia's HAI Link Lab conducted research on how adaptive humanoid robots can be used to detect human emotion and then be used to help comfort patients before painful medical procedures. This became the topic of my technical project; researching how well equipped the NAO robots are in replacing the nurses that would usually comfort children before their procedures. The topic of my STS deliverable relates the ethical dilemmas, specifically the societal inequalities it constructs, that come with CRISPR gene editing to create "Designer Babies". Both projects involve evaluating the ethics behind integrating medical technologies into society and determining if the medical technology's benefits are worth the harms. Similarly, the projects look at how the different technologies may positively or negatively affect the children. With CRISPR gene editing, there is the risk of creating a divide between "edited" and "non-edited" children in the future generations which will only foster more inequality in society. The use of adaptive humanoid robots can similarly affect children in future generations by taking away human-to-human interaction and replacing it with human-to-robot interaction.

The technical portion of my thesis produced an analysis of the accuracy of the software currently being used by the NAO robots to detect facial and vocal recognition in humans and how to better improve the current research process. The results showed that although the robots did successfully recognize and evoke certain emotions, the success was based on research done on a much higher age group than the intended age group of the technology. The robots are intended to be used to combat the declining availability of nurses that provide consistent non-

pharmacological care in pediatric care for children who are about to undergo painful procedures. The individuals who participated in this study were all above the age of 18; however, this software will be used to detect the expression of younger children, likely under 18. Therefore, to further investigate the ability of the robot to comfort the child and assess the success of the software used, observations should be made on the robot's ability to read the facial expression of the children via trials in the pediatric department. These results will directly provide statistics of the software's ability to successfully predict and read the emotion of the child. Based on these results, the software data may be updated or remain the same.

In my STS research, I analyzed the ethical inequalities that would be integrated into society if CRISPR gene editing was to be an accepted medical technology. Overall, the research yielded 3 significant findings: CRISPR will increase the existing gap between the rich and middle class/poor, the technology will create a division between the "edited" children and "non-edited" children, and there will be heightened societal inequalities. These findings coupled with existing regulations against embryo gene editing allowed for the conclusion that "designer babies" is a medical technology with more harmful ethical consequences than medical benefits. Furthermore, with the investigation into the existing case of designer babies in China in which the scientist behind the study is put in jail, the current status quo on such technology is suggested to be maintained worldwide. Though not directly related to the technical project, the STS research conducted also examines a medical technology that would be used on embryos to attempt to create "perfect" children.

By researching both projects simultaneously, I realized how although medically these technologies have increased benefits, their social and behavioral impacts weigh heavier. Both studies demonstrate the mutual shaping of technology and society. Analyzing the technologies

and their ethical effects shows how different STS perspectives can help determine what technologies are ethically moral. In other words, by researching both projects at once I realized that even though these medical technologies have good intentions to better the well-being of children, the long term and broader impacts can only be seen if you assess the ethical and moral capacities of each project. By considering how the technology shapes the society we live in, we can become aware of the larger consequences and future ethical issues that arise with integrating new technologies into our community. This is a takeaway that can be applied to any technology, not just the two explored in the STS and technical topics.

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Technical Project Team Members

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Elizabeth Orrico, Department of Computer Science

Adaptive Humanoid Robots and Pediatrics: NAO Robots

CS4991 Capstone Report, 2022
Meghna Singh
Computer Science
School of Engineering and Applied Science
The University of Virginia
Charlottesville, Virginia USA
(ms2vx@virginia.edu)

Abstract

With increasing numbers of patients in pediatric care and decreased availability of consistent non-pharmacological care in hospitals, the UVA HAI Link Lab is conducting research on how adaptive humanoid robots can be used to detect human emotion and thus be used to help comfort patients before painful medical procedures. The NAO robots utilized in the research use a software that detects human facial expressions. These scans are stored to create a baseline of facial expressions correlated to certain emotions. This baseline enables the robots to predict the emotion correlated to the facial expression of the child in pediatric care. To determine the accuracy of the software used, research studies were conducted via students at the University. The robots were given a set of actions to carry out that we hypothesized would evoke certain emotions, which worked as predicted. Although the robots did induce the anticipated emotion, the software took in facial expressions of research participants who are generally much older than the target audience of this project. In the field, the robots will be interacting with much younger participants and so better research with an audience closer to the targeted age would be a good area of improvement.

1. Introduction

Are robots on the verge of replacing humans? This may just be the case in this research study being done at the University of Virginia. This past semester I had the opportunity to work with UVA's HAI Link Lab and the specific project I worked on was Adaptive Humanoid Robots for Pain Management in Children. This project made use of NAO humanoid robots and increased their interactive abilities through the use of the camera and microphone. With increased capabilities, the robots are able to assess pain and emotion in children that are undergoing treatment in hospitals. The robots detect facial expression, voice emotion, and adapt to each response accordingly. This robot aims to help pain management in children in a non-pharmacological manner that also cheers up the children. Studies are currently being conducted to evaluate how well equipped the robots are to assess the emotions of the children in the pediatric department so that they can be deployed. Currently there are not enough nurses on staff for the hospital to be able to provide non-phrenological support for every child in pediatric care.

If these robots are successful in their ability to assess the mood of human beings and provide proper feedback, they may become a good tool in the hospital. With the short-staffing of the nurses, robots would be able to provide a method of support to the children in pediatric care and in a sense replace this human interaction between the children and nurses.

If nurses are replaced by robots, software being used by the NAO robots must be well equipped to detect the facial expressions of human beings so that the robot's response accurate. If the robot is unsuccessful at providing the correct

response to the child's facial expression, it can result in the child's mood being affected negatively, which can further affect their mental health.

2. Review of Research

The purpose of the UVA study is accurate pain assessment and management in children exposed to prolonged and repeated acute pain (Shenoy, 2021). The work is currently being used to provide a set of entertaining and distracting verbal/non-verbal actions to help brighten the children's mood and lessen discomfort and fear of their painful medical procedures.

Preliminary research in regards to the success of the software has already begun. In October of 2021, the lab conducted studies in which UVA students were recruited to provide facial expression data to the software. The robot was programmed to evoke certain facial expressions from each individual, and these recorded facial expressions were entered in the software. The interactive capabilities of the NAO humanoid robots are increased by the use of the camera and microphone. The combination of these two provides a manner of detection models for "facial expression, voice quality, and adapt the robot's verbal and non-verbal interactive responses for optimal distraction through adaptive behavioral models".

With the combination of these two emotion predictive probabilities, an emotion label is created. The label is then used as input to a "reinforcement learning model with the robot as the agent to choose the best action out of a set of entertaining and distracting verbal and non-verbal actions to cheer up the child and distract them from the pain and fear of the medical procedure" (Shenoy, Sudhir. 2021).

Previous research has been conducted to test the accuracy of the NAO robots' facial recognition. The results from the study are shown in Figure 1 below (Garbaya, 2022). This study illustrates that the accuracy of the NAO robots is perfect for some emotions, but relatively low for others. This is a factor that has been considered in the study being conducted at UVA and has driven the researchers to try to improve the expressions that are a weak spot for the NAO robots.

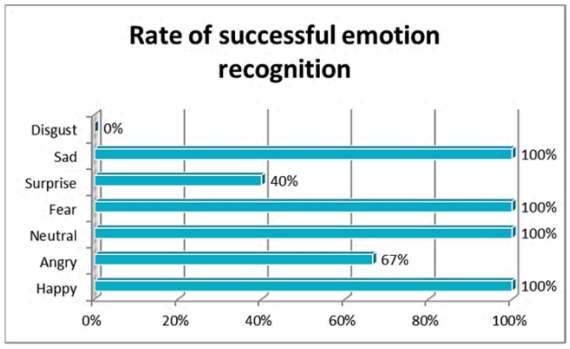

Figure 1: Rate of Successful Emotion Recognition

3. Process Design

The first step in the research was brainstorming ideas on what actions or verbal queues should be made by the NAO robots to evoke specific emotions. For example, to evoke the emotion of fear the researchers thought of different ways to scare the participant, such as telling a scary story or having the robot do a jump scare in the middle of telling a story. Once each emotion had a corresponding action to induce a reaction, participants were gathered to collect facial recognition data.

The participants in the study were recruited via a google form sent out to UVA students, ranging in age from 18-21. Each participant enters a room where the robot and a camera are set up. The student sits down in front of the robot and the camera. The camera is used to capture each participant's reaction to the robot's actions and is used to improve future testing if something goes wrong. The robot goes through a series of actions and verbal queues and records the participant's vocal and facial reaction. This is then used in the software to improve the facial recognition

program. Once these studies are finished and the software is perfected, the robots will be taken to the pediatric department in the hospital.

However, before this, the researchers spent some time in the hospital observing the interaction between the nurses and the patients. By doing this, the researchers collected information on how the nurses comfort their patients and specifically what methods evoke the most positive reaction in the patients. This information noted and is further used to create different action and verbal assistance in the NAO robots. These observations help make more fitting actions than the previously brainstormed ones as they are based on the real life interaction between the nurses and the patients. Once the observations are completed, the software for the robot is updated and then a test trail will be deployed.

4. Results

The study itself is still in progress. The parts that have definite results are the participants in the initial facial reaction gathering. Overall, the process was successful. The researchers were successfully able to gather various facial expressions for different emotions. However, there were a few instances where the robot was unsuccessfully able to evoke certain emotions which may be because everyone has a different reaction to what is “funny” or “sad.” Some participants did not crack a smile when the robot told a joke while others laughed out loud. This creates some discrepancies, but because there were only a few of these outlier data, it did not prove to be a big issue. Additionally, the hospital observations are being proved useful to combat this issue.

The researchers are able to take note of specific words and actions that the nurses say that definitively induce positive or negative reactions in the patients. There are certain words and affirmative actions that help patients, and by taking note of these the researchers are able to re program the software of the robot so it mimics those actions of the nurse.

5. Conclusion

Given the current short staffing of nurses, this research is significant because it can provide a solution to the lack of nurses that are able to help with comforting patients in pediatric care. With not enough nurses to provide comfort to children before they go into painful procedures, the adaptive humanoid robots can provide as a comfort mechanism that these children lack. It is important that the researchers correctly identify and provoke respective emotions from the robot. Extensive trials should be done to make sure the robots have the correct reaction to the emotions the child is displaying.

With successful research, this robot can be a very beneficial tool in helping combat the shortage of nurses. Furthermore, it will help children feel much more comforted before their procedures. The robots have the potential to take away fear from the children and replace it with a playful experience that can ease their mind before they go into medical care. Furthermore, the robots will be able to spend more time with the children in comparison to the nurses which gives the children more time to get comfortable before they go into surgery. Overall, this research project done by the UVA HAI Link Lab has great potential.

6. Future Work

There is, however, one key issue that may challenge the reliability of this data: the age of the individuals. The individuals who participated in this study were all above the age of 18; however, this software will be used to detect the expression of younger children, likely under 18. Therefore, to further

investigate the ability of the robot to comfort the child and assess the success of the software used, observations should be made on the robot's ability to read the facial expression of the children via trials in the pediatric department. These results will directly provide statistics of the software's ability to successfully predict and read the emotion of the child. Based on these results, the software data may be updated or remain the same.

7. UVA Evaluation

This research is being conducted at the HAI Link Lab at UVA. The UVA program did not have much to do with this research aside from Machine Learning. The Machine Learning courses at UVA proved helpful when conducting this research, as the adaptive humanoid robots make use of ML. Additionally, all lab courses taught at UVA proved useful, as a lot of the research done makes use of experimentation processes that are used in labs. If someone were to be a part of this study, it would be beneficial to provide them with some background on the adaptive robots themselves and the software they utilize.

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Advisor
Kathryn A. Neeley, Associate Professor of STS, Department of Engineering and Society

Introduction

There is a "need for urgent discussion of the implications [of embryo gene editing], before genetic selection of embryos for intelligence hits the market" (Ball, 2018). Technology has now advanced to a point where parents can now pick and choose the characteristics of their child, both physical and non-physical. With the rise of bioengineering, there has been increased research and development in the area of gene editing. CRISPR is a system which searches DNA for a gene and then cuts that part of the DNA and adds its own replacement sequence (Miller, 2006). CRISPR then allows scientists to alter the original DNA of an organism and change it to essentially anything they want (that is scientifically possible). Given this capability, scientists will potentially be able to edit and customize the genes of human embryos and essentially create "designer babies". When thinking about CRISPR, a long list of ethical questions arises. What social ethics should be considered when determining if gene editing should be used? Does CRISPR gene editing in embryos effect the existing inequalities amongst society? These are some of the questions that show us we do not fully understand the cons of the technology – we know the benefits but how harmful are the effects?

These fears, however, are not new. "Concerns over designer babies rose to the public consciousness decades ago when recombinant DNA technology and in vitro fertilization (IVF) were being developed, and again when Dolly the sheep was cloned" (Witkowsky, 2017). Although CRISPR is impressive, it creates numerous ethical and moral dilemmas. In fact, it creates a group of ethical issues that have never been questioned before given that the technology is so foreign. One of the largest consequences and changes that needs to be thought about is the concern of the future societal impact that this kind of gene editing may have—specifically in regards to the furthering of inequality. Given that this technology allows

scientists to modify their embryo before it is born, this can "create a divide between those who are genetically modified and those who are not" (Fitzgerald, 2018).

To evaluate the risks of CRISPR gene editing in embryos, it is important to look at similar technologies and research the bioethics that have been involved to be able to identify pre-existing issues. By looking at related instances of medical technology and existing regulations placed against the technology, it becomes possible to predict how CRISPR will affect the future of society and why it has not become accepted on a larger scale. This will demonstrate that the pros of the technology do not outweigh the cons. Looking at the existing ethical stance on designer babies by evaluating the regulations placed on current research and existing cases of designer babies such as the case of the twins in China, a comparison between the medical benefits and the consequences they cause is completed. By analyzing via these methods, it is found that the use of CRISPR in embryos will heighten the social inequality by increasing the gap between the rich and the poor while also amplifying differences amongst individuals in society and these findings can better prepare us for future conversations.

Part I: Designer Babies and the Ethical Dilemmas they Possess for Society

There have been previous efforts to question the impacts that this technology may have on society, and regulations have been previously set to prevent the negative effects. One such regulation exists in the UK where the Human Fertilization and Embryology Authority. "frames binding regulation after careful deliberation and acts as a brake so the technology does not outrun the debate". In fact, the director of the European Bioinformatics Institute in Cambridge states that embryo selection "needs robust regulation that society can be confident in because leaving such a matter to unregulated market forces is dangerous" (Ball, 2018). The fact that such regulation is already existing in other parts of the world illustrates that there has been a

prior understanding that such a technology can become potentially harmful if introduced into society and this same understanding should persist in future discussion. In the United States, congressional committees have voted to continue federal bans on creating genetically modified babies. Not only does the ban forbid the creation of genetically modified babies, but it also prohibits the FDA from considering any proposals to try and use genetically modified embryos to try to establish pregnancies (Stein, 2019). Again, this is a demonstration of the fact that there is already a pre-existing effort being taken place to prevent this medical technology from being integrated into society and can be helpful precedent in future conversations.

To recognize the controversy surrounding CIRPSR and the regulations that are placed on the use of the technology, the public view on CRISPR should be analyzed. Figure 1 illustrates that when it comes to using CRISPR, most of the U.S. adults find it to be appropriate if the technology is used to "treat a serious disease/condition the baby would have at birth". On the other hand, they do not find it to be appropriate if the technology is used for other characteristics such as "making the baby more intelligent" (Funk, 2020).

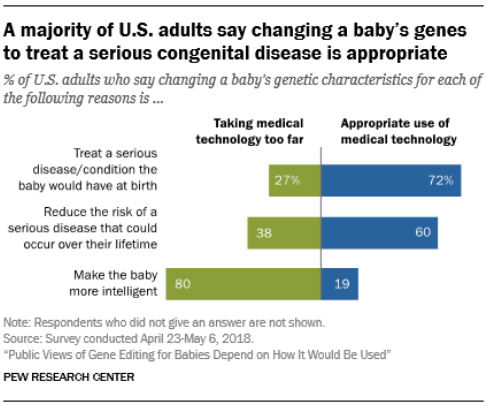

Figure 1: % of US adults who say changing a baby's genetic characteristics for each of the following reasons is…(Funk, 2020)

The results of this chart in combination with existing regulations clearly illustrates the existing notion that there are certain "right" and "wrong" uses of this medical technology.

However, although there are benefits to this technology, if this technology were to be implemented for those benefits there is no guarantee at what the limit for the CRISPR gene editing will be. Will it stop at genetic disease editing, or will it go beyond into editing of characteristics? Regardless, even if the technology is introduced for genetic disease removal, the same problems will occur: only the rich will be able to afford the technology, this will give the rich an advantage, and the gap between the rich and under privileged will broaden. The results from this poll and the regulations discussed above provide a guidance on the public and political opinion on CRISPR gene editing. This can be used in conversation to predict future trends regarding the opinion the general public will have on the use of CRISPR gene editing in embryos.

The process of genetic editing in embryos is not a cheap one. Naturally, that would make this technology only accessible to those that are wealthy and individuals of the middle/lower class would not have access to this technology. This brings the discussion of the inequality such technology would bring into society. Currently, companies such as Spark Therapeutics plan to charge US patients $850,000 for gene therapy which treats a form of blindness in children and with that being said, there is very little reason to expect that further gene editing procedures would be cheaper (Bessen, 2019). The rich already have advantages such as better access to healthier lifestyles as they have the financial ability to participate in better medical care, buying healthier food, and less extraneous lifestyles. Having access to CRISPR gene editing would only further benefit the rich and leave those that cannot afford such a procedure at more loss. If CRISPR were to become an expensive commodity that is only accessible to the rich, they would have the ability to give their children an unfair advantage in the economic competition against the middle and lower class. Furthermore, “a future in which

rich people are able to make themselves more entrepreneurial, smarter, more socially adept or more charismatic than other people could lead to exacerbation of the recent trends of falling economic mobility and increasing inequality" (Smith, 2018). With that being said, this would then create a divide between the rich and the poor. Babies from wealthier families would be genetically modified and they would be able to make their children smarter, more athletic, just to name a few, while children from less fortunate families would be left with their "normal" genes. This would have lasting impact on the future society as this divide would not be lifted unless the technology was accessible to all individuals. With only some families having access to such technology due to the financial costs of gene editing, there is clear inequality present and this inequality is important to be discussed in future conversations.

CRISPR gene editing can also then decrease genetic diversity and increase social inequality. Although this tool is a powerful one, it can also harmfully reduce human diversity and increase social inequality by "editing out the kinds of people that medical science, and the society it has shaped, categorize as diseased or genetically contaminated--people like us who are understood as having bad genes" (Sufian, 2021). For example, there may be a standard set by the wealthy and they may begin to create babies according to that standard. That standard would only be met by families with access to the technology while families with no access will be left unable to create embryos that "meet" these criteria. This would naturally create a social divide while also lowering genetic diversity. With no indication of when CRISPR will be accessible to everyone in society, the negative feedback loop in which the poor continue to struggle more while the rich continue to get better medical access will only broaden. It is this feedback loop which is important to evaluate in future conversations about CRISPR gene editing to reflect on how the relationship between the rich and poor will be altered.

Although there are benefits to CRISPR gene editing, if this technology were to be implemented for those benefits there is no guarantee at what the limit for the gene editing in embryos will be. Will it stop at genetic disease editing, or will it go beyond into editing of characteristics? Regardless, even if the technology is introduced for genetic disease removal, the same problems will occur: only the rich will be able to afford the technology, this will give the rich an advantage, and the gap between the rich and under privileged will broaden. This creates the same cycle as discussed above. This brings into question the benefits and consequences of CRISPR, both of which are influential in conversations in the future.

Part II: Analysis of the Benefits Provided by Genetic Editing in Embryos; Chinese Designer Babies

This section utilizes the framework from Pacey's work, specifically his use of tables to organize and compare themes, to compare the benefits provided by genetic editing via CRISPR and the associated ethical dilemmas. Furthermore, the organization of facts into table as done by Pacey will be used to analyze the existing case of designer babies in China. By formatting the existing facts into tables, it will be easier to compare the differing perspectives regarding the effects of designer babies in both a medical and ethical perspective, similar to the example tables in Pacey's work.

The first case of designer babies has been implemented in China. A Chinese scientist created the world's first genetically edited twins. Here, we can also use Pacey's tool of organized tools to analyze the benefits and consequences that were a result of this new technology and the results can be used in future conversation when evaluating if genetic editing in embryos. Figure 2 illustrates the results of the first case of designer babies in regards to the scientist and the twins themselves.

Consequence/Benefit Overall	Consequence/Benefit for Scientist	Consequence/Benefit for Twins
The research conducted and the response of the court illustrates how society has a unified standing on the issue of gene editing – as it was deemed unacceptable by higher courts.	Placed under arrest because the Chinese courts agreed that such a technology has violated medical regulations.	The twins were genetically altered to be resistant to HIV.
"The experiment was met with fierce criticism around the world and inside China. Scientists said the use of genome editing served little medical purpose and could have introduced errors into the girls' genomes." (2018)	Has not been released from jail and his medical license has been taken away preventing him from conducting other research and medical procedures.	The babies face a higher risk of premature death – illustrates how foreign the technology really is as there is no confirmation that it will be successful and it may result in fatal error.

Figure 2: The differing consequences of the Chinese designer babies

Figure 2 illustrates that the existing use of CRISPR to create designer babies with specific genes of the parents' choice had more consequences than benefits. In fact, this research itself has led to countries around the world to pass laws that regulate the use of human embryos. A majority of countries with advanced research programs have laws or guidelines in place that either ban or restrict genetic modification of human embryos for reproductive purposes. In fact, "even the first two countries to use CRISPR in human embryos for research purposes, China and the UK, explicitly prohibit initiating a pregnancy with genetically modified human embryos" (Sufian, 2021).

There are many benefits that scientists have described to exist with the use of CRISPR gene editing on embryos. However, with these benefits are associated ethical issues that have

been reflected in previous research/medical technologies. Figure 3 describes some of these benefits and the associated ethical stance.

Scientist's Benefits	Ethical Issue	Ethical Benefit
"improve the baby's health...the chances of genetic disorders can be reduced. For instance, it does not only decrease a baby's chances of being affected by certain health conditions but increases a baby's chances of survival as well" (Sunny, 2020).	Those who do not have access to this technology will not have the ability to provide their embryos with these benefits. This will lead to inequality in the sense that the rich, who already have better chances of living longer, will have an additional method of increasing their lifespan while those that are middle/lower class may not have access to this technology.	This enables parents, and the child themselves, to avoid the hardships and possible burden (both economic and social) that is placed on the life of a child with an incurable disease.
"Genetic editing allows a new pathway where future generations may become naturally immune to such diseases" (Sunny, 2020).	Widens the social gap between those who are able to afford this new treatment and those who are not – richer will be able to be immune to such diseases while the rest will continue to risk suffering these diseases.	Will create a healthier society overall as new and better genes are passed down with each generation.
Parents are able to choose the attributes they desire in their embryo.	With parents picking and choosing each gene, the uniqueness of each individual is lowered. It also provides the enhanced with an unfair advantage over those that have not had their genes engineered.	There is an ability to enhance the overall health, intelligence, and other traits of the embryo.

Figure 3: The contrast between the medical benefits provided by CRISPR gene editing and the associated ethics behind the benefits

Figure 3 illustrates how with each medical benefit, there is an associated ethical benefit and issue to be addressed. Each medical benefit's respective ethical issue illustrates an area for future conversation. By putting these thoughts into a table, we are able to form different areas of discussion which may not be thought of prior. To further strengthen the statements in the table, we can analyze the previous instances where genetic editing has helped the immunity of society.

One prime example of medical technology being used to build up immunity in the gene pool are vaccines. Vaccines can be seen as a similar technology in the sense that it lowered disease in the gene pool and overall created a healthier group of humans. This relates to the benefits of designer babies because designer babies provide parents to be able to remove genes which may result in future disease. By doing so, a healthier gene pool will be created as scientists would be genetically removing disease from embryos (Greta, 2020). However, we can see in today's society that there are many "anti-vax" individuals as well. The antivaccination is a growing sentiment in the country and a large contributing factor to this is the "hotly disputed link between immunizations and autism". Furthermore, "increasing numbers of parents are refusing immunizations for their children and seeking legally sanctioned exemptions instead, apparently fearing vaccines more than the underlying diseases that they protect against" (Calandrillo, 2004).

This illustrates that even with existing medical technologies, there are individuals who have some ethical issues with the technology that overtake the benefits. Again, with the research of existing medical technologies similar to CRISPR we are able to clearly define the different results. With clear organization of these results, it is easier to predict the outcome of CRISPR in future conversation. Another example of such research is the case where researchers infused a 44-year-old's patient blood with gene-editing tools to combat his Hunter

Syndrome (Kaiser, 2017). The treatment has been successful in treating his Hunter Syndrome which further illustrates some of the medical benefits associated with gene editing. However, this was an expensive treatment that would not be affordable by all which then brings into question some of the ethical issues that are referred to in Figure 2. Again, this also would aid in future conversation as it serves as an example of existing consequences and benefits of medical technology similar to CRISPR.

With the analysis of both tables and existing research, relevant facts related to gene picking in the embryos become prevalent. With new found facts and ethical issues, there is a baseline to steer future conversation about CRISPR. Furthermore, there are answers to questions such as how CRISPR will promote the creation of a bigger gap between the rich and poor or how CRISPR will create inequality amongst the future children.

Part III: Is the medical technology worth the risks?

The use of CRISPR to edit genes, based on the observations made asbove, have clear benefits and consequences. While there are medical benefits to this technology which better the future gene pool of our society, based on the analysis in the above paragraphs via the creation of the tables the hypothesis can be made that the consequences may outweigh those benefits. There are clear ethical and moral problems with the use of this technology, specifically in relation to the inequality that arises in society. The flow chart below illustrates one example of such inequality. With the introduction of CRISPR gene editing into society, we are able to see how it could easily heighten the gap between the rich and poor due to how inaccessible the technology is. As mentioned before, it becomes a mechanism which gives the rich a further advantage in living a healthier and longer life while those who cannot afford the procedure are left to deal with the medical consequences. While those who get the procedure get access to a life with lower chances of disease and a longer lifespan overall, those who cannot utilize

CRISPR face the common risks that we all do today. We can see this outcome using the flow chart illustrated below which gives an example of what would happen if CRISPR were to be introduced into our current society. The flow chart can be then used to facilitate future conversation about how the use of CRISPR will affect society.

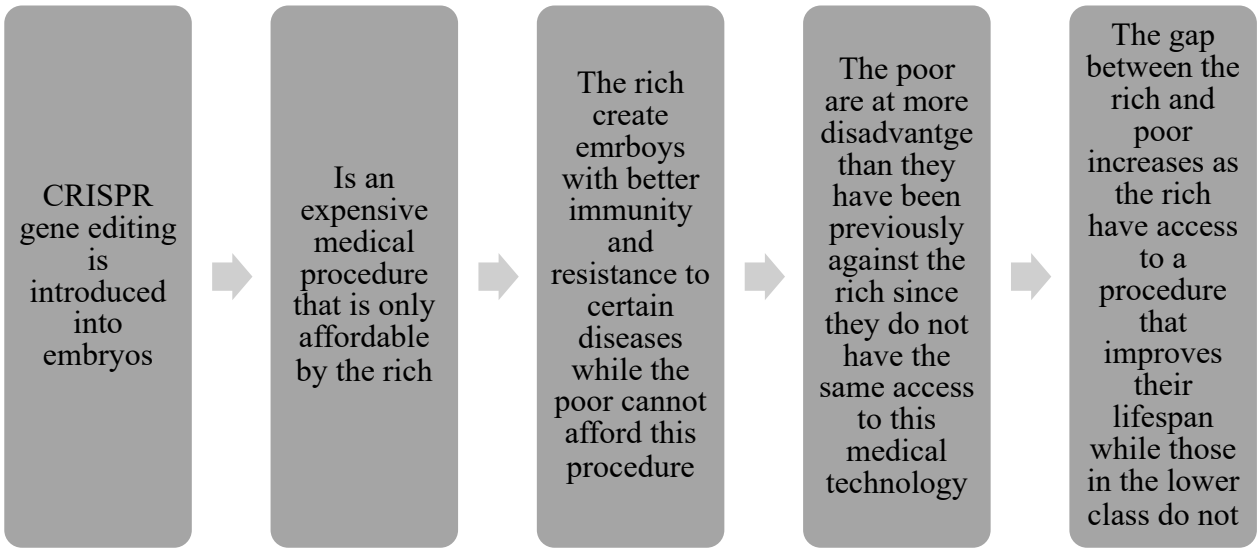

Figure 4: Heightening of the gap between the rich and poor as a result of the use of CRISPR on embryos

While there are also medical benefits, as listed in Figure 5, the medical consequences lead to several ethical issues that highlight how they outweigh the benefits that come with this technology, also listed in Figure 5. Although by editing out genes in embryos we can eradicate many diseases in our future society, there is great risk that comes with its use as shown in the table. Not only are there medical consequences, however, there are also related ethical consequences. With the picking and choosing of genes by parents in their babies, not only do we reduce the gene pool of society and increase inequality, but we also encourage the setting of a new standard in society. There comes the possibility that certain genes will become more

"desirable" and these will only be present in those that can afford the procedure: the rich. Furthermore, the baby gains no say in which genes they will have when they grow up which in turn brings in the question of morality in giving the parents full authority to create a baby according to their own desires, not the desire of the child. Such a scenario is described in Figure 6.

Medical Benefit	**Medical Consequence**
Immunity against certain diseases	Affects gene pool of society
Attributes of embryo can be chosen my parents	Not enough research done in the area on the long-term effects
Increased lifespan	If a gene is incorrectly "fixed" it can cause an accidental termination of pregnancy
Can prevent disability	Genes may be multi-tasking
Facilitates better organ transplants	Violates the rights of the babies who have no say in what genes they get
Can choose traits beyond the physical aspects such as IQ	Creates possibility for unwanted mutations

Figure 5: The medical benefits versus the medical consequences of CRISPR gene editing in embryos

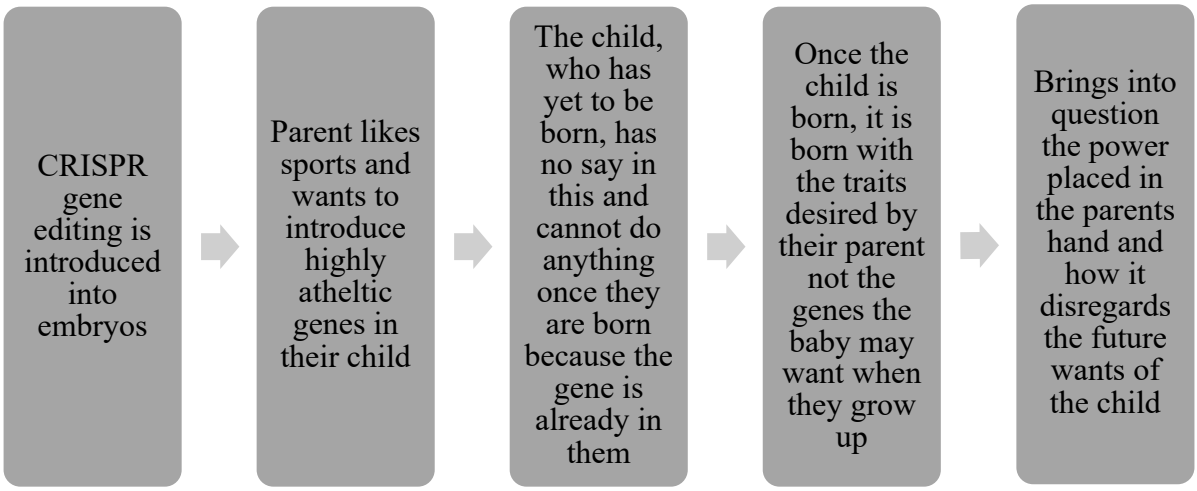

Figure 6: How CRISPR gene editing can lead to inequality for the embryo

With the analyzation of current medical technologies in place, we are able to see how there will always be some consequence or ethical dilemma when it comes to technologies which cause a medical shift in society. These consequences can serve as a basis for future conversation as well since the flow charts above illustrate situations that may occur in the future.

One such technology that can be used as an example for the future is the development of vaccines, as shown in Figure 7. With vaccines, we also saw how it became socially acceptable to get them even though vaccines can be linked to causing autism in some cases. However, when looking at CRISPR we are looking at a large difference in the ethical consequences.

Furthermore, medically vaccines have been well researched while gene editing in embryos is still a fairly new area of study. With such limited research, the reaction is still very strong against CRISPR in comparison to vaccinations. In fact, as mentioned previously, it has been banned in countries such as the UK and China, while vaccinations are available

everywhere in the world. The analysis of vaccines and the creation of the flow chart in Figure 7 is another example of how using existing research to extract facts can then be applied to CRISPR gene editing as we can use the trends to predict future outcomes.

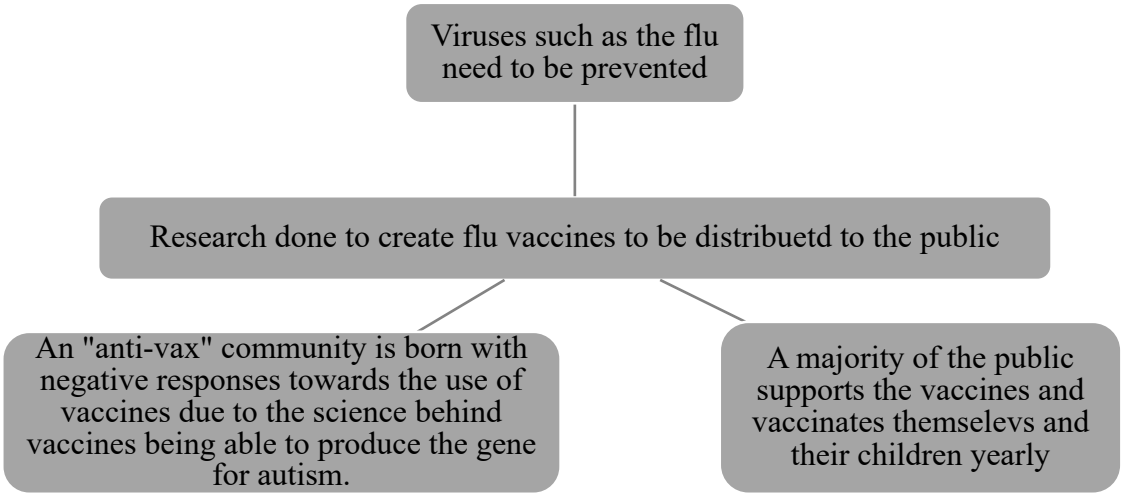

Figure 7: Analysis of Vaccines as a Medical Technology

Overall, the paper illustrates how although being able to create babies with lower risk in developing certain life-threatening diseases, the medical and ethical consequences far surpass the benefits. By putting these analyses into tables and flow charts, there is a basis that can be created for future conversation about CRISPR gene editing. It is in the best interest of society, if equality is wished to be maintained, we should continue following the global standard set around genetically editing embryos: don't do it. If CIRSPR is debated in the future, these flow charts and tables can serve as a reminder of the consequences and benefits that is provided to society.

Conclusion

The tables and flow charts created in this paper can prove to be beneficial for future scientists working with CRISPR as it can aid in swaying them to use/not use this technology for the greater good of society. The research and comparisons made above regarding the medical benefits and consequences of designer babies illustrate how CRISPR editing in

embryos has a large factor in the mutual shaping of technology and society, and it serves as a ground for future conversation. The various tables and flow charts can aid in future conversation about how technologies that involve children should involve the thought of evaluating how their future will be affected, as well as how the future of society would change as a result. We are able to very clearly see that the results of the use of CRISPR, aside from the benefit of a better and healthier society, are consequences that affect our society today and in the future which lay the ground for conversations if CRISPR is to be used in the future. In fact, it will have a lasting negative impact that will only further create divide in the world we live in and thus the findings from the above flow charts and tables are imperative to be discussed. When considering the use of CRISPR gene editing in embryos, scientists should thoroughly discuss some of the ethical and medical consequences that are listed above. They should also consider the pre-existing rules and global stance on the matter and use it as a guide to direct future research and use of this medical technology.

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Adaptive Humanoid Robots and Pediatrics

Designer Babies and the Potential Equality they Threaten

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Science

By
Meghna Singh

Spring 2022

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Kent Wayland, Department of Engineering and Society

Daniel Graham, Department of Computer Science

General Research Problem:

Medical Engineering and its Effects on Children

How will advancements in medical engineering effect the future of children and the society they grow up in?

In 1796, Edward Jenner conducted a small potentially fatal experiment on a child. He applied pus from cowpox lesions on the hands of the young child, and after a couple of days of illness the child recovered successfully and Dr. Jenner then injected the boy with matter from a smallpox blister (Hollingham, R. 2020). The child did not develop smallpox and neither did anyone who came in contact with him, which led to the vital discovery of the smallpox vaccine (Hollingham, R. 2020). This discovery which came about from the experiment on the child led to the global eradication of small pox. This vaccine was given to children, and it eventually created a society that is immune to the disease. With this medical development, society was immediately bettered since global eradication of diseases was being facilitated—and it was being facilitated via children (Greta Keenan, P. S. 2020). This is just one of many examples where medical engineering has had a direct effect on children, and with this comes the question of ethics – specifically social ethics. It is clear in the example previously that the potentially fatal clinical trial was by no means ethical, and this same dilemma is posed with newer medical engineering research.

There has been a great amount of development in the field of medical/biological engineering. Two such technologies, which will be discussed in this paper, are (1) adaptive humanoid robots and (2) CRISPR designer babies. Ethical dilemmas are posed by the use of both technologies—specifically social concerns. A large concern would be the impact such technology would have on children that will be using the technology versus those that will not be

using it. Based on how the technology affects the child, their altered development will result in an altered society—and this altered society is something which we must pave the path for. It also raises political issues such as the concern of how legal it is to use these technologies. This is an important issue to discuss, as the rapid growth of medical engineering will bring a large array of issues in light, that need to be discussed prior to their integration into society. With medical engineering affecting the future of children first hand, it is imperative that we as a society consider the positives and negatives of the social ethics that come with the technologies and the cost society will take if some children are given improved lives over others.

Adaptive Humanoid Robots and Pediatrics

How well equipped is the software that is used by the NAO robots in detecting the facial expressions of human beings? How accurate is the robot's response to the facial expressions?

This past semester I had the opportunity to work with UVA's HAI Link Lab. The specific project I worked on was Adaptive Humanoid Robots for Pain Management in Children. This project made use of NAO humanoid robots and increased their interactive abilities through the use of the camera and microphone. With increased capabilities, the robots are able to assess pain and emotion in children that are undergoing treatment in hospitals. The robots detect facial expression, voice emotion, and adapt to each response accordingly. This robot aims to help pain management in children in a non-pharmacological manner that also cheers up the children. Studies are currently being conducted to evaluate how well equipped the robots are at assessing the emotions of the children in the pediatric department—which will be the main topic of discussion. This section will focus on the software that is used by the NAO robots and will assess its ability to correctly identify an individual's facial expression and relate it to the

respective emotion. It is important to research how accurate the software is because it is via the software that the robot will detect the children's emotion. Thus, it is crucial for the software to have a high success rate in order to comply to the child's mood and provide the correct response. If the software itself is not accurate, then the robot will not properly read the child's emotion and may respond with the wrong action which then could only further ruin the mental state of the child.

Currently, there is an understanding that the purpose of this study is mainly due to the high importance of accurate pain assessment and management in children exposed to prolonged and repeated acute pain (Shenoy, Sudhir. 2021). The work is currently being used to provide a set of entertaining and distracting verbal/non-verbal actions to help brighten the children's mood and lessen discomfort and fear of their painful medical procedures (Shenoy, Sudhir. 2021). Preliminary research in regards to the success of the software has already been done to a certain extent. In October of 2021, the lab conducted studies where UVA students were recruited to provide facial expression data to the software. The robot was programmed to evoke certain facial expressions from each individual, and these recorded facial expressions were entered in the software. There is, however, one key issue that may question the reliability of this data: the age of the individuals. The individuals who participated in this study were all above the age of 18, however this software will be used to detect the expression of younger children (likely under 18). Therefore, to further investigate the ability of the robot to comfort the child and assess the success of the software used, observations should be made on the ability for the robot to read the facial expression of the children via trials in the pediatric department. These results will directly provide statistics of the software's ability to successfully predict and read the emotion of the child. Based on these results, the software data may be updated or remain the same.

Designer Babies and the Potential Equality they Threaten

Does CRISPR gene editing in embryos effect the existing inequalities amongst society? What social ethics should be considered when determining if this technology should be used?

We have entered an era where parents can now pick and choose the characteristics of their child, both physical and non-physical. With the rise of bioengineering, there has been increased research and development in the area of gene editing. CRISPR is a system which searches DNA for a gene and then cuts that part of the DNA and adds its own replacement sequence. This technology then allows scientists to alter the original DNA of an organism and change it to essentially anything they want (that is scientifically possible). In our case, say the parents of a child wanted their boy to have blue eyes and blonde hair. The CRISPR technology would search for the eye color and hair color gene, take out the existing gene and then insert the correct DNA sequence that ensures blue eyes and blonde hair. Given this capability, scientists will potentially be able to edit and customize the genes of human embryos and essentially create "designer babies".

Although this technology is impressive, it creates a long list of ethical and moral dilemmas. One such dilemma is the concern of the future societal impact that this kind of gene editing may have—specifically in regards to the furthering of inequality, which will make the basis of this paper. With the idea of creating "perfect" babies, if this technology were to become a prevalent part of society some children would be genetically wired to be better than other children. This creates a huge ethical dilemma in regards to equality.

When looking at the inequality that comes with such technology, two basic views will be discussed in depth: (1) designer babies will result in a society that is more divided and will

encourage inequality and (2) that this modified genetic pool is for the greater good of society as it creates a healthier society that may become immune to certain diseases (McCabe, L. L., & McCabe, E. R. B. 2008). In order to fully encompass all parts of each argument, research will be conducted on each view thoroughly via the journals from which these views stem from. Furthermore, arguments posed for and against each view will be discussed in depth in order to fully critique each view and determine the inequality that will be created between the "enhanced" and "unenhanced" individuals.

Additionally, to further emphasize the inequality that lies within this technology, research will be conducted on existing technologies that have caused inequality in society in the past. This will be done via existing ethical papers that discuss the impact of different technologies on society—specifically those that amplify inequalities. One such technology that will be discussed and researched further is the development of vaccines and inequalities. Additionally, data from the current study on the Chinese twins—the current "designer babies"—will be gathered to further consider how they have advantages or disadvantages from others in society. The main process of collecting data would be to gather information for both sides; (1) designer babies are a valuable asset to society and the inequality is worth it, and (2) the inequality that comes with designer babies is not worth the technology's benefits. Once both sides have enough data gathered for them, it will be easier to find an answer to the research question at hand.

Conclusion

Using CRISPR as a gene editing tool has many benefits, especially for aspiring parents. The thought of being able to create your perfect baby is very appealing on the forefront, but delving deeper brings out the social ethics it poses which is illustrated by the end of this project.

It can clearly be seen that there are both benefits and negatives that come with this technology, and hopefully by the end of the project it will be shows which weighs more heavily. This knowledge will be beneficial for future scientists working with this technology and could aid in swaying them to use/not use this technology for the greater good of society. Overall, the entirety of the project has illustrated the mutual shaping between society and these medically engineered tools. The paper should illustrate that both the technologies discussed go hand in hand with the society they form as a result. Furthermore, it emphasizes the direct role that society and our ethics plays in the technology we choose to provide to individuals. The work done in this paper will aid future conversation about how technologies that involve children should involve the thought of evaluating how their future will be affected, as well as how the future of society would change as a result.

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