Robots - Inanimate or Living: To Evaluate the Receptivity of Xenobots by Indian Respondents

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ABSTRACT

As industrialization continues, the world is introduced to many challenges, such as Global Warming and Pollution. Even with adverse effects on the environment, synthetic materials continue to be commonly used. To tackle this, scientists from the University of Vermont combined the fields of AI and bio-technology to develop a robot capable of performing specific functions e.g, locomoting and manipulating objects, using *cells*. Other than reducing the use of synthetic materials, this robot can directly help in collecting microplastics from the ocean, while being biodegradable. With time, as manufacturing gets automated, the capability of these robots will be widened. Though it's not an immediate concern, the idea of a living robot can be seen to come with many ethical concerns. To understand the reservations it can create, this research paper intends to evaluate the receptivity of Xenobots by high-school students and teachers. A total of 30 respondents from various urban and suburban locations of the country were surveyed on their knowledge and interest of Xenobots, before and after watching an informational video, and their thoughts on its ethical concerns and effectiveness were collected from open-ended questions. Qualitative and Quantitative tools such as t-tests, mean, SD tests and thematic analysis were used to study the accumulated data. The video positively impacted their rating of knowledge, however interest remained equally high. Further thematic analysis revealed that respondents were doubtful about its usefulness as well as its drawbacks, which notifies aspiring companies and governments that it might be too soon for such technology.

Introduction

Using cells to build robots has been a major step taken towards a sustainable living. With commonly used materials like steel, plastic, concrete being ecologically harmful, a biodegradable material like tissues from a frog embryo, gives rise to a possibility to create 'living robots' (Ball, 2020), capable of tasks such as locomotion, object manipulation, object transport and collective behavior. Other than the large number of possible applications, these properties of the Xenobot allow scientists to further their understanding behind the working of cells and their communication.

A 'living robot', or 'novel living machines', refers to the concept of using cells to create a robot capable of performing desired tasks (Ball, 2020). These stem cells include cardiac progenitor cells and epithelial progenitor cells, taken from frog embryos at their blastula stage. These two play different roles in the working of the bot - the cardiac cells use 'electrical activity' to achieve contractions, which are used by the robot for locomotion; while the epithelial cells serve as 'passive tissues' which provide the structure (Ball,2020). The arrangement of these two types of cells dictates the functionality of the robot, and therefore specific configurations are produced using evolutionary algorithms that would best suit the target task. Finally, microsurgery is performed manually and the xenobot is engineered.

Professors J. Bongard, S. Kriegman, D. Blackiston, and M. Levin, from the University of Vermont and Tufts university, 2020, have been the major contributors to this research. Their work in this field has led to the identification of several properties of Xenobots, which are useful in indicating potential applications of the robot. Their properties include:

- Locomotion: Keeping net displacement as the primary factor, multiple trials were conducted over sets of initial design (Kriegman, 2020). The best of each trial was then shortlisted and went through further selection. Once a final design is selected, manufacture begins. This motion is caused due to the contracting of the cardiac cells, pushing against the surface of the dish.
- Object Manipulation: This is made possible as the moving body of the Xenobot hits particulate matter found externally and causes displacement in it. This can be evolved by specifying target locations from which to remove any particles or remove only certain specified particles (Kriegman, 2020).
- Object Transport: The bot has also been simulated with a hole near its center (in the transverse plane), which can be used to carry an object as the bot moves.
- Collective Behavior: When Xenobots are placed together, the interaction between multiple of these show chances of 'collective behavior'. One instance of this behavior is the way two xenobots form a 'temporary mechanical bond' upon colliding, and revolve around each other before releasing tangentially (Kriegman, 2020).
- Self-healing: While most other materials used to build robots can be damaged easily, Xenobots retain the ability to self-heal after being cut open using forceps.

As AI and Biotechnology progress, it can be understood that Xenobots will be further improved, to the possibility of having the ability to reproduce (Coghlan, 2020). This however, raises some ethical concerns - Are Xenobots *organisms* or are they *robots*? Due to its different properties, there have been many potential applications identified, which tackle some of the most critical problems that mankind faces as of this point in time. However, with the pros of its functionality, also come the doubts about how it could be used alternatively i.e, in a harmful way. Boldt & Muller (2008) found that the gap between 'manipulating' and 'creating' life has not yet been bridged - giving rise to the aforementioned doubts. It poses multiple potential threats such as the possibility of being used to deliver harmful substances inside the human body during warfare or for assassinations, leading to questions about the connection between Science, specifically Bio-Tech, and weaponry (Coupland, 2005). It is also further speculated that with the ability to procreate, these could also be harmful to the environment's natural cycles if present in large numbers. Another major ethical concern is one involving the continuous evolution of living beings, bringing up possible chances of advanced neural networks gaining sentience (Coghlan, 2020). These, although still aspects of speculation, were some interesting matters to consider as one learns about Xenobots.

With the direction the environment is headed towards, it's becoming increasingly important to use sustainable and biodegradable materials. Here, using cells as the primary material, there is a new way in which we can use these biodegradable robots in numerous ways to solve increasingly prominent problems. With the ability to manipulate objects, Xenobots raise the possibility of collecting microplastics in the ocean into clusters, which can then be removed manually. Furthermore, if made from the stem cells of the body, Xenobots (in this case, Biobots, since they aren't made using Xenopus Cells), can be used to deliver medicine intelligently, or to the required part, as well as detect cancer at its early stages to increase chances of prevention and treatment. These are some invaluable uses of the robot, not just for a specific sector of the world, but for the prosperity of the environment and mankind.

Methodology

Research Aim

The aim of this research study was to evaluate the impact of a self-formulated video on the **knowledge** and **interest** of Indian respondents towards xenobots — "living, self-sustaining robots" — as solutions for critical human problems, using a mixed-method approach.

Research Approach

An online pre-post survey that would be distributed to Indian respondents aged 14 and above would measure the changes in their **knowledge** and **interest** regarding the usefulness of xenobots for solving challenging human problems, such as environmental degradation, dealing with illnesses by intelligent drug delivery, identifying cancer or removing plaque from artery walls; as a result of their viewing of the video. Their perceptions would be obtained through quantitative ratings and textual responses to open-ended questions.

Hypothesis

- 1a. *Null hypothesis:* There would be no significant difference in the mean ratings of the interest of the viewers towards Xenobots before and after watching the video.
  1b. Alternative Hypothesis: There would be a significant difference in the mean ratings of the interest of the viewers towards Xenobots before and after watching the video.
- 2a. *Null hypothesis:* There would be no significant difference in the mean ratings of the knowledge of the viewers about Xenobots before and after watching the video.
  2b. Alternative Hypothesis: There would be a significant difference in the mean ratings of the knowledge of the viewer about Xenobots before and after watching the video.

Informed Consent

All respondents were informed that their confidentiality and privacy would be maintained. No identifying information was collected or disclosed in the paper. All ethical guidelines of research were followed, and consent was taken from each participant. (Refer to Appendix to see invitation letter)

Sample

The respondents to the survey majorly consisted of high-school students from urban and suburban areas throughout the country. With a total of 30 responses, the survey was based in English, targeting English-fluent people for participation.

Tools Used

Composition of the educational tool: An informative video was created, to be used as an education tool which would provide the respondents with the information necessary to take the survey.

Design of the questionnaire: The survey consisted of a closed-ended and open-ended questionnaire to evaluate the respondents' perceptions of the xenobots. The questions were divided into three sections:
The First Section contains questions about the demographic characteristics of the respondents that can be used to allow for an in-depth analysis of the responses of the respondents by different segments, such as gender and educational level.

The Second Section posed questions about the respondents' knowledge and interest on the topic and its applications, before watching the video.

The Third Section consisted of the informative video, while the Fourth Section covered the same questions about the respondents' knowledge and interest on the topic of study after watching the video to determine whether there had been any change. Moreover, it also elicited their assessment of the specific applications of the xenobots.

Finally, the section also evaluated the relationship between the respondents' ratings on these applications and the respondents' ratings of knowledge and interest.

Data Collection Procedure

The survey was distributed using various social media platforms, and shared with teachers, to have a varying range of age, and years of schooling, academic qualification, etc. This was done, as with a large number of respondents, demographic information of such factors, could help generate comparisons between these segments. Respondents were also asked about their ratings, thus yielding textual responses to open-ended questions.

Data Analysis

With a mixed method approach, both quantitative and qualitative data was analyzed. Descriptive and inferential statistics were calculated by performing paired t-tests, to determine perceptions towards the usefulness of Xenobots. The respondents' responses to open-ended questions were also very useful in eliciting the respondents' unique perception of the Xenobot. The overall analysis of the data was then situated within the context of the background data gathered and the literature.

Results

Mean, SD, paired t-test and thematic analysis were conducted to evaluate the overall receptivity of Xenobots by the Indian population. Several factors of demographic data were also collected to understand the relation between background data and the level of receptivity.

A majority of the respondents were students. These included students spread out over grades 9-12. It can also be noted that the rest include teachers, doctors and psychologists. (Refer to Appendix Table 5 for further detail) More than half the respondents were interested in STEM, while the rest are divided between Humanities, Commerce, and Undecided. (Refer to Table 6 in Appendix)

Quantitative

Table 1: Mean and Standard Deviation values for all quantitative responses

Factor	Mean	Standard Deviation
Interest - Before	3.73	0.99
Interest - After	3.8	1.21
Knowledge - Before	1.55	0.98
Knowledge - After	3.34	0.92

Table 1 consists of the mean and standard deviation values for the respondents' ratings on the factors: Knowledge and Interest, before and after watching the informative video.

Table 2: Summary of T-test Analysis on variables Interest and Knowledge, before and after a short informative video (N=30).

Source	Before		After		t	p
	M	SD	M	SD		
Knowledge	1.55	0.98	3.34	0.92	-11.21	0.00
Interest	3.73	0.99	3.8	1.21	-0.30	0.38

Respondents, after watching the informative video, (M= 3.34, SD= .92) reported significantly higher levels of knowledge about Xenobots than before (M=1.55, SD= .98), t(1) = -11.21, p< .05. This conclusively proves hypothesis 2b, and therefore null hypothesis 2a can be rejected (Table 2).

Furthermore, Respondents, before (M= 3.73, SD= .99) and after (M= 3.8, SD= 1.21) watching the informative video, did not differ significantly on levels of interest, t(1) = -0.30, p > .05. Due to this, alternate hypothesis 1b can be rejected, and null hypothesis can be confirmed. (Table 2)

Qualitative

Table 3: Thematic Analysis of the responses on Ethical Concerns raised by Xenobots.

Theme	Example quotes
Unemployment The introduction of automation can threaten a large number of professions, leading to unemployment.	Replacement of humans in professions Decreasing scope to decrease poverty
Lack of Ownership Since these bots are made of cells and capable of gaining neural networks, their decisions aren't controllable. This raises concerns regarding the entity responsible for the bots actions	Since these robots are 'living', any decisions they make can be completely independent of the creator's control Who should be responsible for the consequences of the actions of these robots? The wealth generated by the AI - Who should get it? How should it be distributed?

Misuse of Technology Xenobots are microscopic robots with limitless potential applications. Thus, another concern raised by these robots are its potential misuses, where it is used to harm rather than help.	Used in warfare and weapons like many inventions before these Used for hostile biological purposes
Useful/Uselessness Because of their size and availability, Xenobots also give rise to doubts about their efficiency	microscopic structures won't be of any use hard to create

Table 4: Thematic Analysis of the responses on Effectiveness of Xenobots.

Theme	Example quotes
Applications Xenobots, and other such technologies in the future, can be used to solve a large number of problems for the environment.	early detection of illness used in initiatives like #TeamTrees& #TeamSeas get into places which are not accessible by external tools,
Advantages Due to its applications, Xenobots tend to serve several general purposes. These are its main advantages.	solve major environmental problems. advancement of technology and medicine improve human life and health
Uncertainty These robots are extremely potent, but due to their status of living beings, and robots they also raise concerns regarding unpredictability.	solve the same amount of problems they would create too early for such a technology

Thematic analysis was carried out and certain themes like Uncertainty and Misuse of Technology were extracted from the data.

Discussion

As provided in the results section, tables 1 and 2 provide basic demographic data about the respondents. A majority of the respondents were students from grades 9-12, while others included teachers and doctors.

At around this age, most students get an inclination towards which subject they would like to choose for higher studies, giving rise to the second dataset for demographics. It was speculated that the field of interest of such respondents would play a role in determining their thoughts and reservations about the idea of 'living robots'. For example, students inclined towards STEM were speculated to be more interested and less concerned with the idea of robots being made from cells.

As the information in Table 3 indicates, there is significant change in the mean ratings of the respondents' knowledge of Xenobots(Before: M=1.55, SD= .98, After: M= 3.34, SD= .92). This can easily be understood since the idea has received little recognition, and therefore enables the respondents to learn a lot more about it.

Table 3 also shows that the change in the mean ratings of the respondents' interest was insignificant, which can be explained due to the initial mean rating being quite high. The ratings of interest before watching the video (M= 3.73, SD= .99) portrays that even unknown, the idea of a 'living robot' intrigued the respondents at a great level. With a high initial value, there is little room for improvement which explains the almost negligible change in the mean ratings.

Next, moving to the Qualitative data that was collected, the doubtfulness regarding the ethical concerns raised by Xenobots, become more evident from the responses. Some themes brought up include -

Misuse of Technology: This is the area that respondents viewed as one of Xenobot's potential downsides. Like with a lot of the upcoming technology, it can be suspected that Xenobots too will have uses in warlike situations; Lack of Ownership: Since living robots lie in the grey area between organisms and robots, it becomes difficult to determine who is responsible for their positive or negative effects on the world. While this may seem like an issue for the future, Xenobots are only the beginning of a new era in biotechnology, and issues like this get more important as the field progresses; Doubts on Effectiveness: Two other themes regarding the shortcomings of Xenobots can be categorized together as the respondents' doubtfulness about the bot's efficiency. These are unemployment, where Xenobots can be seen replacing humans in some professional environments, which brings up the issue of its effect on the world's economy, and efficiency, where respondents showed concerns about how effective these robots could be with their size, as well as compared to the work put into making them.

The doubtfulness of Xenobots can be seen throughout all these themes. Areas of concern regarding these robots according to the respondents matched the speculation that Xenobots could be used to harm people after entering their body. It can also be seen that the respondents took this a step further by mentioning that someone would have to be responsible for their misdeeds.

Further, to get a comprehensive view of the respondents' takes on Xenobots, their thoughts on Xenobots' applications were also recorded. Some themes that can be noticed here include: Advantages - Most respondents viewed this new technology for its major advantages such as: 'solving environmental problems' and 'improving human life and health'. These can be seen as some of its general uses, which are possible due to its applications; Applications: Respondents also mentioned some of its applications as the benefits of this technology. These include their accessibility into places that aren't penetrable by external tools, early detection of illnesses, etc; Uncertainty: As a continuation of the doubtfulness mentioned above, a major theme of the responses was uncertainty. The viewers felt concerned about the possibility that Xenobots may 'solve the same amount of problems they would create', or that it is ' too early for such a technology.'

Implications

With the informative video providing adequate detail about Xenobots, this research paper helps spread awareness of the idea of a 'living robot'. This would be relevant when major healthcare departments of the government need to evaluate people's perception of such technologies. Further, the paper also serves as a source for future generations to understand various reservations the current population has towards the fusion of life and technology.

Conclusion

The research study was intended to evaluate the impact of a self-formulated video on the **knowledge** and **interest** of Indian respondents towards xenobots. Through the means of an online survey, respondents' ratings were compared

before and after the informational video. These results conclusively proved that there was a significant change in the viewer's knowledge of Xenobots, and an insignificant change in their interest.

Further, the general receptivity of Xenobots by these respondents was studied using thematic analysis of their views on Xenobots' shortcomings and effectiveness. In both fields, there is one common attitude towards the idea of 'living robots' - skepticism. Most responses displayed a sense of doubt towards this idea and these came in recurring themes such as - Uncertainty, Lack of Ownership, and Misuse of Technology. This skepticism suggests that work needs to be done in clearing such ethical and technical concerns , before such potent robots are introduced.

With time, this research can be extended into understanding how the receptivity towards such ideas changes with each decade, which would be helpful in understanding how far technology has evolved, as well as play a role in spreading news of this possibly life-changing technology.

Limitations

With the broad aim of understanding the receptivity of Xenobots by Indians, the number of respondents restricted the accuracy of this data. With about 30 respondents, the collected data cannot be accounted for a demographic as large as the Indian Population. This research also had to focus on ideated applications of these robots since they haven't been tested yet, therefore it also creates a sense of doubt about how effective it will be in reality.

Acknowledgments

References

Ball, P. (2020). Living robots. Nature materials, 19(3), 265-265.

Coghlan, S., & Leins, K. (2020). "Living Robots": Ethical Questions About Xenobots. The American Journal of Bioethics, 20(5), W1-W3.

Coupland, R., & Leins, K. R. (2005). Science and prohibited weapons. Science, 308(5730), 1841-1842.

Kriegman, S., Blackiston, D., Levin, M., & Bongard, J. (2020). A scalable pipeline for designing reconfigurable organisms. Proceedings of the National Academy of Sciences, 117(4), 1853-1859.

University of Vermont. (2020, January 13). Living robots built using frog cells: Tiny 'xenobots' assembled from cells promise advances from drug delivery to toxic waste clean-up. ScienceDaily. Retrieved January 31, 2022 from www.sciencedaily.com/releases/2020/01/200113175653.htm