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The Social Implications of Household Robotics

An Interactive Qualifying Project Report

submitted in partial fulfillment of the requirements for the

Degree of Bachelor of Science by

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Abstract

This project aims to investigate the social implications of artificially intelligent household robots. By examining the history of robotics, researching the industry, performing surveys, analyzing relevant literature, and conducting personal interviews, the project discusses the future prevalence of household robotics.

Table of Contents

Table of Figures

1. Introduction

1.1: Defining the Robot

Robots possess an intricate and varied past which makes them difficult to rigidly define. In a conventional sense, a robot is considered a task-driven machine, designed to physically interact with the surrounding environment. This operation is autonomous, performed based on the robot's programming. Some modern views broaden this definition, stating that robots include both mechanical entities and software programs that use at least some level of artificial intelligence to perform tasks (Stafford, 2007).

Some robots that are considered within this second definition include the program-selection system used in TiVo, the anti-skid technology used in some recent automobiles, and even a household dishwasher. For this project, a specific definition has been adopted: as long as the machine or software exhibits artificial intelligence by evaluating and performing tasks in the real world based on its own decision making, it is a robot.

A standard definition of robots differs even within experts of robotics; for example, the Australian Robotics and Automation Association agrees on no standard definition (MacDonald). Some researchers and roboticists, maintain a conventional view, whereas others prefer a more modern approach. Within the scope of this project, the modern, inclusive definition is used.

1.2: A History of Interest in Robotics

The rich history of robots begins long ago, before the inception of computers.

The Ancient Greeks were “fascinated with automata of all kinds,” apparent in their speculation and mythology (Isom, 2005). Aristotle once wrote of the desire for a tool that operated automatically, doing “the work that befits it” (Isom, 2005). Two examples within mythology include the artificial bronze man Talos crafted by Hephaestus and the artificial voice produced by Daedalus.

Moreover, this fixation with automata is apparent within not only Greek mythology but also the automatic tools they used. The water clock, invented by Ctestibus of Alexandria, served as one of the first mechanical timepieces, which operated automatically (www.fi.edu).

Figure 1: Drawing of the Greeks' water clock (physics.nist.gov).

These early examples, however rudimentary, paved the way for future advancements that led up to the creation of what would traditionally be recognized as a robot. As interest was generated through new inventions and media, the reality of the robot became more apparent. Within the field of robotics, Isaac Asimov is famous for his Three Laws of Robotics. Within his compilation of short stories on robots "I, Robot" in 1950, Asimov listed three integral rules that all robots must follow (robotics.megagiant.com):

> *1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.*
>
> *2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.*
>
> *3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.*

The Three Laws of Robotics have become popular and have influenced the growth of interest in robotics. These laws appear in both moral debate and various media of entertainment; one example is the Mega Man X video game series, the premise of which is based on the first robotic law and adherence to it.

The not-for-profit organization FIRST (For Inspiration and Recognition of Science and Technology) also deals with Asimov's laws within its goals . FIRST is designed to "inspire young people's interest and participation in science and technology" through programs and competitions to build "self-confidence, knowledge, and life skills" in the robotics field (www.usfirst.org). The robots crafted within FIRST's activities adhere to these laws.

The significance of FIRST manifests in its celebration of robotics. As teams come together to put their innovation to the test, new ways to approach problems are explored by its participants. With friendly competition that promotes professionalism, FIRST helps stimulate interest in engineering and robotics (www.usfirst.org).

This interest in robotics has fluctuated over time, but has increased steadily since the days of Asimov. Today, rapid advancements in technology have spurred even more curiosity towards the industry. However, the emergence of robots designed to be used in the household opens a relatively new field, serving as its own subsection of robotics. Because of this, there is little experience in understanding the full social impact of household robots; they have not yet become prevalent. To this end, it is helpful to understand how popular household robots are, how popular they will become, and from what this popularity results or will result.

1.3: Project Objective and Scope

By obtaining an understanding of current trends and opinions, the investigation seeks to determine how prevalent artificially intelligent household robotics have become and how prevalent they may become in the future.

The first method used by the investigation is a survey of people of all ages and locations. In order to reach this larger scope, the main portion of the investigation was performed online. An additional portion, conducted via mail and described further in section 3.2, targets the population of Cape Cod. In both scenarios, the population includes people of varying educational, financial, and cultural backgrounds to obtain a wide range of results and to identify patterns. These types of patterns will include different levels of robotics expertise, whether experienced or naïve.

The inclusion of all ages is done to include a greater scope of opinion. Input from senior citizens is just as important as input from teenagers; each demographic provides a unique outlook on technology that is important to consider when examining results and producing the conclusion.

Cape Cod was chosen as an additional focus study. By using only online submissions, the survey would include only input from those who own a computer, thus introducing bias. Some people do not own or use computers; this is a portion of the population that would be missing from the main investigation. The mail version is designed to capture their input.

1.4: Research Questions

The project's research is based on finding opinions. To this end, it utilizes surveys and interviews to learn what people think. There are a number of research questions considered throughout the project's research and data collection:

1. How comfortable are people with the advancement of artificially intelligent robots in the household?

2. What kinds of robots are people using now?
3. What kinds of robots will be popular in the future?
4. What kinds of tasks are people comfortable with assigning to robots?
5. How quickly will the public reception of household robots change?

By analyzing the responses to these types of questions, the investigation identifies patterns to predict the growth of the popularity of robotics. Moreover, the answers to these questions further the project's research, helping to identify the increasing prevalence of artificially intelligent household products.

1.5: Project Structure

First to follow is an examination of background information required for understanding. This includes a look at intelligent behavior, which covers the relationship between human actions and robot actions. Discussion then leads to human-machine comfort, which evaluates how robots are accepted in social life. The background section finishes with a look at current developments, drawing together relevant information about the social implications of robotics.

We will next discuss the procedure taken in evaluating popular opinion on robots. This will go over the process taken in crafting the project, including the creation of the survey, the structure of the interview process, and the methods devised for the data analysis section.

The procedure follows in the final portion of the report. The results section deals with the survey data, interview outcome, and statistical analysis. Finally, the conclusion section ends the report with a summary of the findings and an examination of the potential of robotics.

2. Background

2.1: Intelligent Behavior: Social Interaction

Before delving into the particulars of household robotics, it is necessary to gain an understanding of the history of studies in intelligent behavior and their impact in a social environment. There are many factors which may influence the social implications of robots using high-level artificial intelligence; a machine that attempts to interact with a human will elicit various user responses.

Within the robotics industry, making this interaction as natural as possible is the goal; the idea is that a robot should successfully mimic human behavior in both task completion and social interaction (www.electronicsteacher.com).

At this point, the study of robotics enters social psychology. One aspect is imitation, or the ability for an artificially intelligent entity to judge others' actions and copy them. This interaction helps forge a level of trust in intelligence, which relates to the sense of camaraderie that is forged through this act. Kerstin Dautenhahn discussed this phenomenon within a 1995 study on robot autonomy and its social implications, stating that such behavior is "crucial for the development of individual interactions and social relationships" (Dautenhahn, 1995).

Understanding the root of various psychological behaviors is important in crafting a natural artificial intelligence for robots. Kimbler highlights this importance within a 1984 paper on the history of robotic applications and their eventual role as direct companions. He discusses the notion of a robot not as an auxiliary aid, but as an extension of the self. Beginning with a preliminary look at Asimov's vision of robotics, Kimbler addresses the fact that needs and uses for personal robots may arise.

Matching robot behavior with natural, human-like actions serves as the most important factor for smoothing the interaction between human and machine. The aim is to make people feel as comfortable as possible as they work or play with a robot.

2.2: Examining Human-Machine Comfort

Measuring a person's comfort with a robot has become important for social implications studies of robotics. A robot may be well-designed and efficient at completing its designed task, but if it is not received well or if it generates feelings of discomfort, it will see little household application.

In the course of evaluating popular opinion on comfort with household robots, the project examined prior studies within the field. One experiment conducted by K. L. Koay, et al. in 2006 involved the application of direct human-robot interaction (Koay, 2006). In an effort to understand the factors involved with human comfort, seven people were exposed to twelve different robot behaviors as part of an interaction trial. Such behaviors included exhibiting "robot action, proximity, and motion relative to the subjects." The study found a lack of comfort during situations when the robot became obtrusive or remained in very close proximity with the person (Koay, 2006).

However, the potential of human comfort with robots is influenced by another factor as well. The robot's behavior serves as a major product in determining human comfort. Because of this complexity, studies and evaluations on robot design and interaction can greatly vary in their scope.

Examining behavior in particular is a 1994 study conducted by Maja Mataric in her work at the MIT Artificial Intelligence Laboratory (Mataric, 1994). Mataric discusses the learning strategies of various robotic agents, the behavior of which is at the core of complex robot interaction design. Similar to the study of imitation conducted by Dautenhahn in 1995, the observation of and reaction to other agents' behavior work on basic interaction principles: "what is good for one, is good for another, at least indirectly." This ideal allows an artificially intelligent entity to try different behaviors that are not directly beneficial, but may benefit others (Mataric, 1994). As robots learn to interact with each other using human-like judgment, the potential for natural human-robot interaction increases.

Extending these interactions to human-machine levels is the final step in programming and judging proper robotic behavior. As an additional step in understanding the complexities within human-machine comfort, examining what people want robots to do can also serve as a method through which comfortable robotic behavior can be discerned. Evaluating the human role in this view of comfort is the other half of the issue; the project uses the survey to try and reveal with what kinds of robots people are comfortable.

2.3: Current Developments Point to the Future

As the project aims to examine current trends, analyzing the latest developments of robotics companies is important in determining the potential social prevalence and acceptance of household robots. Some developments improve on currently-existing hardware; others are new inventions with new innovations.

One of the most popular segments of the commercial robot industry, household robot vacuum cleaners are being continually improved with new features and upgraded functionality (Kahney, 2003). iRobot's Roomba, one of the most prevalent household cleaning robots in the United States with over two million units sold (www.appliance magazine.com, 2006), is designed to automatically navigate randomly across the floor, programmed with intelligence to be able to avoid falling down stairs, adjust itself for different floors, and follow around furniture (www.irobot.com).

With new versions come new advances in intelligence. An article on the development of robot vacuums covers some prior advancements (Kahney, 2003). Electrolux, a robot vacuum company based in Europe, has developed the Trilobite. Although much more expensive, it has been designed to be able to navigate rooms by ultrasound and keep track of an internal map of the area. In addition, it automatically recharges itself. Similar to the Trilobite is the RoboCleaner by Germany's Alfred Kärcher. The RoboCleaner is capable of emptying its dust container (Kahney, 2003).

More recent developments in 2008 show even more promise. The newest home inventions by iRobot include pool-cleaning robots and gutter-cleaning robots (www.irobot.com). Joining the Roomba is Verro, a self-contained robot filter that cleans both pool debris and bacteria, and Looj, a gutter-purging robot that removes leaves and pests. These new robots highlight the increasing level of chore-automation as new robots are introduced to the home. Supporting this claim of automation is Helen Greiner, cofounder of iRobot, who states “in 30 years chores around the house will be a thing of the past” (Torrone, 2004).

This line of robots serves as an example of future developments. Colin Angle, fellow co-founder of iRobot, discusses the future tasks of robots in a similar vein. He states, “Our true mission is to make homes that can take care of themselves” (Clark, 2006). Moreover, Angle touches upon earlier studies in intelligent behavior. As described in Kimbler in 1984, the robot will serve as an extension of the self, as “the line between robot and human is going to blur. Already today you've got people hearing with cochlear implants, and there's early work with artificial eyes” (Clark, 2006). This suggests a strong future presence for home robots.

Home-automation is receiving excellent coverage, with robots such as the Robomow for lawn mowing (www.friendlyrobotics.com). More complex tasks are also being studied. Space Daily discussed the potential of cooking robots in an article on AIC-AI, which “is capable of Sichuan, Shandong and Canton cuisines and can cook thousands of Chinese dishes (www.spacedaily.com, 2006).

However, home-automation isn’t the only part of the industry receiving attention. The Nabaztag is a friendly robot that tells its owner the news and weather (www.nabaztag.com). Home protection is also considered: in 2002, Kuriko Miyake of PC World discussed Sanyo’s Banryu, a robot that “can sense intruders or smoke” and is marketed as a “household security robot” (www.pcworld.com, 2002).

The robotics industry has so far followed some of the trends hoped for by roboticists; current robots inspire new innovations, such as the Roomba paving the way for the Verro. However, interest in household robotics is not as strong as initially hoped. Angle mentions that "skepticism surrounding robots continues," which makes dispelling apprehensions as important as designing new robots (Ganapati, 2007). Regardless, roboticists such as Moravec, professor at Carnegie Mellon University, project that household robots will follow the trend of other household appliances—slow but eventual popularity (Kahney, 2006).

3. Procedure

3.1: Early Analysis

In the process of completing the project, many design decisions were made and changed throughout the course of the year. The reasons for these changes ranged from research and planning choices to data collection and analysis procedures.

During its first stages, the project was based on determining the topic focus and researching the history of robotics and artificial intelligence. Some of the explored topics included natural language research and human-computer interaction It explored several possibilities within these initial topics, examining how people interacted with intelligent machines and how they felt about them. Gradually, more attention was paid to human comfort with robots. As more research was done, the project focus shifted to domestic robots, such as iRobot's Roomba, a floor-vacuuming robot. Finally, the project combined these last two concepts to form its final and current focus: the social implications of household robots.

3.2: Determining Methods

Once the main topic had been decided, the next phase of the project involved the method by which it would investigate the issue. Based on early studies of human-computer interaction during the project, it was determined that the best way to understand the social implications and future possibilities of household robots was to obtain the thoughts and opinions of people, both expert and non-expert.

The first level of data collection was the demographic survey, designed to obtain insight from many people with varying backgrounds. By spreading the survey using multiple media, the survey would reach as many people as possible by different means. This survey would be responsible for determining the level of robotics expertise and technological background of the participant, as well as their opinions of both general robot concerns and specific robot functions.

The target audience was all people of all backgrounds—the strength of the survey is the number of people it can reach and the variance in the types of participants that take part. With a large and varied audience, the project would be able to make a more definitive analysis of popular opinion. The information afforded by the survey would allow for multiple analytical comparisons to be made, not only between people of different experience, but also between individual responses. The way some people feel about one aspect of household robotics may influence another aspect.

The second level of data collection was the personal interview. This was designed as a more specific and detailed version of a survey, where more information was provided by a single person. Most of the interviews were based on expert opinion—the participants were selected because of their experience with or knowledge about the robotics field. However, some interviews were performed with non-experts to provide a basis for the expert opinion and obtain a personal look into the feelings and impressions of those with less expert viewpoints.

3.3: Reasoning and Rationale: Survey Questions

The creation and distribution of the survey was the main focus for the data collection portion of the project. Because the survey needed to determine both expertise and opinion, it was divided into appropriate sections. The first section was based on identifying experience; the participant was asked to provide information related to their level of education, current occupation, and amount of robotics knowledge. This was followed by a series of questions designed to help further define the participant's experience, such as asking them to rate themselves on a scale and whether they had heard of particular robots, conventions, or practices.

The second section was responsible for determining overall comfort with robots. A list of robots for various tasks was given, and the participant was asked to rate how comfortable they were with each one. Some of the robots selected for the survey were chosen because they were already available for purchase or in development, such as the cleaning robot, lawn mowing robot, news and weather robot, and home automation robot. All of these had multiple real-world counterparts. Other robots mentioned in the survey were based on future concept designs or lesser known inventions. Examples of these robots can be seen in section 2.3.

The third section of the survey was similar to the second—it featured the same robots but instead asked the participant to identify an appropriate cost for each robot from a list of choices. Given a range of values, the participant would select a reasonable price. This information would be used in juxtaposition with the information from the second section for learning how comfort and cost are related and what kind of impact those factors make on the popular opinion of household robotics. This relationship is further explored in section 4.3, with a discussion of popular opinion in section 5.

The fourth and final section introduced some open-response questions designed to ask about specific issues, such as identifying potential concerns and discussing robots that people are looking forward to. This section provides an additional look into a participant's view of robotics, taken into account during the pair-wise analysis in section 4.2.

The survey was kept simple and concise. Although more information could be useful, a long-winded survey can be counter-productive, leading to reduced interest in replying and less focus on the given questions. Additionally, the survey advertised the option to enter a free raffle for a gift certificate as an additional incentive for completing and returning the survey. The winner received a $50 gift certificate to Best Buy.

3.4: Reasoning and Rationale: Interview Process

The interview design followed a similar process. Each interview was divided into two parts—robot scenarios and future projections. In the first part, the interviewee was told about three robots from the survey (the cooking robot, the news and weather robot, and the home-automation robot) and asked to provide their opinions about each one, including their level of comfort and the kind of price they would pay. After giving this initial information, the interviewees were asked to expand on this information in a particular scenario. For example, if the cooking robot had been released several months prior, had become very popular, received excellent reviews, and was well-recommended by many people, would their feelings change in either category? These questions and scenarios help provide a more detailed look into a person's thought process when dealing with robot interaction and comfort.

In the second part, the interviewee was asked to give their opinions about the future of robotics. Would they purchase robots such as these for their home? How popular do they think robots will become? Questions such as these help show not only what both experts and non-experts expect for the future, but also how they would react in a world where household robots had become much more prevalent.

3.5: Reasoning and Rationale: Data Analysis

During the data collection process, two methods of analysis was considered: Overall Value Summation, which was first chosen but later rejected, and Pair-wise Comparison, which was adopted for use.

Using Overall Value Summation, each participant would be rated by two numbers. One represented their overall comfort with robots, and one represented overall willingness to purchase robots. These ratings were obtained by recording their responses to each question. By mapping a value to each survey question response and finding the sum of the participant's responses, a generalized, overall value is yielded that can be compared to other participants.

There were three sets of values to be used in this method: one based on the robot's complexity, one based on the robot's level of social interaction with the user, and one based on when the robot is projected to be available for use. Each question was assigned a weight based on their influence in each category. For example, the robot that cleans floors is not as complex as the others, rarely needs to interact with the user, and is already available for purchase. Thus, it would hold a low weight in determining overall values. In comparison, the robot that cooks meals rates higher in all of these categories. A participant that was willing to purchase and use both robots would obtain a much higher overall value than one that was only interested in the cleaning robot.

However, this method was eventually rejected during the data analysis process in favor of a new method. Although a valid form of data examination, using overall values was not the most effective way to present the findings of the survey because of the difficulty in rationalizing the weights for each question and supporting the reasoning for their selection.

The second option, which was selected for use, was Pair-wise Comparison. This process takes the data from two survey questions, gleans any pattern that can be ascertained in their relationship, then compares this pattern to the rest of the analysis. This process is described in more detail in section 4.2.

After processing the data, an additional statistical analysis method was adopted to supplement the Pair-wise Comparison. Using the Rank-Correlation Coefficient, the results of the survey are further examined. In particular, the analysis is done using Charles Spearman's correlation, which helps detect the strength of the relationship between comfort level and willingness to purchase (Weisstein, 2008).

3.6: Methodology

The survey was distributed using a five-page paper version and an online version. The paper version was mailed to residents throughout Cape Cod, using addresses obtained in the local directory. A mail version was desired because relying on the internet for responses would limit the potential audience and would miss a segment of the population that does not use computers. Reaching these people is important in order to maintain a varied audience and get a larger range of results. Cape Cod was chosen because much of its active population is elderly and is less likely to use or rely on the internet, which is the portion of the audience that the online version is likely to miss. In order to expedite the return of these surveys, return envelopes were provided.

The online version of the survey was generated and hosted by QuestionPro.com, which maintained participants' responses. The survey phase lasted for one month, after which the survey was stopped and the website version was removed.

Once the survey phase was complete, the project focused on interviews. Two non-experts were chosen: George Grivaki and Kiki Kouvaris. Grivaki is a young adult in college who has only just started using computers for the first time. Kouvaris is an elderly woman who uses few electronics in her daily activities.

In addition, five experts were chosen. One was Dr. Fredrik Linaker of Accenture Technology Labs in France, who provided expert opinion based on his experience with the industry. The others were Michael Ciaraldi, Brad Miller, Robert Lindeman, and Kenneth Stafford, professors at Worcester Polytechnic Institute with varying experience in the computer science and robotics fields.

3.7: Survey Sample

The following five pages serve as a sample for the survey.

Survey

Computer Science Department

Hello, my name is Vasilios Mitrokostas. I'm a student at Worcester Polytechnic Institute conducting a survey among fellow Cape Cod residents as part of a research project.

I would greatly appreciate it if you took a few minutes out of your day to please answer these questions. There are two ways to complete the survey—by standard mail or through the internet. **You may choose whatever is most convenient for you**.

Mail address:

Website address:

Everyone who submits a survey can optionally enter a raffle to receive a **$50 gift certificate to Best Buy**, which will be mailed to you.

The survey ends on **February 28, 2007**. If you are interested in the results of the survey, you can check them out at the above website address on March 1, 2007. Thank you very much!

If you wish to enter the raffle, please provide your mailing address:

____

____

____

Please circle or write your responses to the following questions.

1. How old are you? ____

2. Are you male or female? ____

3. What is your occupation? ____

4. Do you have any science or engineering expertise? __________________

5. How familiar are you with current robots and the robotics industry?

1	2	3	4	5
(Generally unfamiliar)				(Very knowledgeable)

6. Do you own any robots at home? If so, what kinds?

____

____

____

____

7. Have you heard of floor cleaning robots (such as the Roomba)?

Yes No

8. Do you know about the FIRST Robotics Competition?

Yes No

9. Have you heard of security robots (such as surveillance or patrol robots)?

Yes No

10. Have you heard of medical robots that are able to perform surgery?

Yes No

The following is a list of household robots, both current and potential. How comfortable would you feel owning one of these robots?
Please circle your choices below.

Robots that . . .

11. clean or vacuum your floors:

1 (Very uncomfortable)	2	3	4	5 (Very comfortable)

12. mow your lawn:

1 2 3 4 5

13. organize and dispense your medicine when you need it:

1 2 3 4 5

14. tell you the news and weather each day:

1 2 3 4 5

15. can converse intelligently with you using voice:

1 2 3 4 5

16. are responsible for calling for help during an emergency:

1 2 3 4 5

17. prepare and cook meals:

1 2 3 4 5

18. guard your home against intruders:

1 2 3 4 5

19. automatically turn on and control lights and appliances:

1 2 3 4 5

The following is a list of household robots, both current and potential. As the price comes down, at what price would you consider buying it?
Please circle your choices below.

Robots that . . .

11. clean or vacuum your floors:

    $400 $300 $200 $100 Would not buy

12. mow your lawn:

    $900 $700 $500 $300 Would not buy

13. organize and dispense your medicine when you need it:

    $400 $300 $200 $100 Would not buy

14. tell you the news and weather each day:

    $200 $150 $100 $50 Would not buy

15. can converse intelligently with you using voice:

    $900 $700 $500 $300 Would not buy

16. are responsible for calling for help during an emergency:

    $400 $300 $200 $100 Would not buy

17. prepare and cook meals:

    $2,000 $1,500 $1,000 $500 Would not buy

18. guard your home against intruders:

    $900 $700 $500 $300 Would not buy

19. automatically turn on and control lights and appliances:

    $700 $500 $300 $100 Would not buy

Please write your responses to the following questions.

20. Is there anything about current or potential robots that you are uncomfortable with or fear?

____

____

____

____

21. How do you feel about the reliability of robots?

____

____

____

____

22. Are there current or potential robots that you are looking forward to trying (such as the automatic lawn mower)?

____

____

____

____

23. Are there currently available robots that you dislike? If so, why?

____

____

____

____

4. Results and Data Analysis

4.1: Raw Survey Results

The survey turnout was promising: 861 participants responded (including both paper and online versions). Using bar graphs to display the responses for each question, this section will describe the data as it was obtained from the survey. Additional, integrated analysis is performed in section 4.2.

Of all 861 participants, 163 (19%) responded that they had some sort of science or engineering expertise. The following graph displays responses for how familiar participants were with robots and the robotics industry.

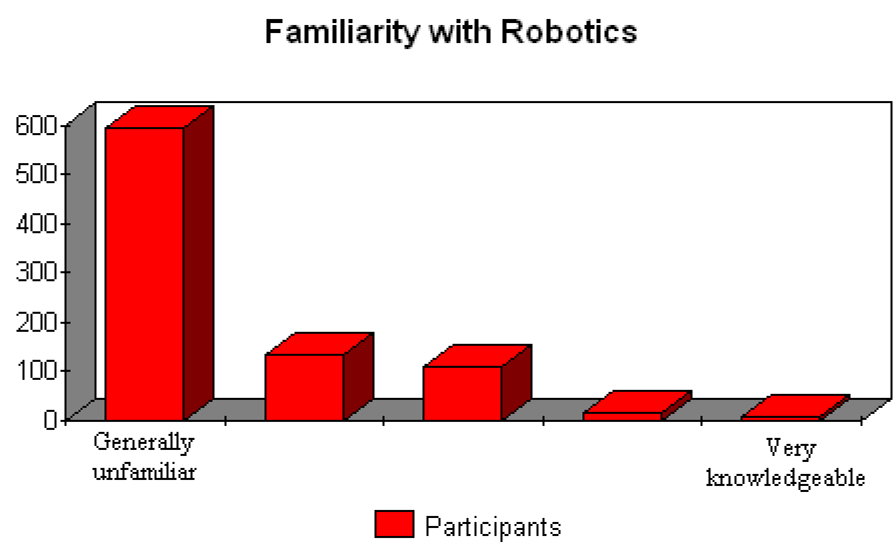


Figure 2: Chart summarizing the responses to robot familiarity.

Most participants were not quite familiar with robots. However, 320 (37%) participants had heard of cleaning robots such as the Roomba. Only 16 (2%) people owned robots, in each case the Roomba itself.

The remaining questions followed in the same vein. 23 (3%) participants had heard of the FIRST Robotics Competition. Less than 1% of the participants had heard of either security robots or medical surgery robots.

The large number of people knowledgeable about the Roomba is a testament to its increasing popularity. Despite low overall knowledge in the robotics industry, many people recognize the classic floor-cleaning robot.

The final four questions of the survey dealt with open-ended responses about robots. Most people did not leave answers in this section, and those that did left short responses. However, there were some interesting results. Very few people reported fears or discomfort about robots; the ones that did remarked on the future. One participant responded, "I don't want them taking over my job." Another said, "I don't think I could live with a robot," a sentiment shared by a couple more respondents.

As far as the reliability of robots goes, responses were mixed. 152 (18%) of the 861 participants stated that robots today are not reliable; however, some people were optimistic about the future. One participant noted, "Probably not now, but I can see them getting better," a remark that 34 of the 152 concurred with. 185 (21%) of the 861 respondents instead said yes to the reliability of robots with comments such as "I feel comfortable with robots," and "There's no problem with robots right now."

Some people were eager to try a robot in their home. 210 (24%) of respondents said that they would be willing to try using a cleaning robot, such as the Roomba. Another 95 (11%) admitted to being eager for future developments. One respondent mentioned, "Just make the massaging robot, and I'll be happy."

The final question on current robots that are disliked was left unanswered by nearly all participants. Only a couple reported some frustration with the Roomba.

Figure 3 is a chart that summarizes the responses to each question in the comfort category. Each task on the left represents a currently or potentially available robot that the participant was asked to consider. For each robot, the participant labeled how comfortable he or she would feel owning it. The responses range from 1 (very uncomfortable) to 5 (very comfortable).

Tasks:	**1**	**2**	**3**	**4**	**5**
Clean floors	9	3	45	52	**752**
Mow lawn	69	52	65	86	**589**
Organize medicine	20	79	99	203	**460**
Tell news and weather	4	45	60	49	**703**
Converse intelligently	**380**	220	102	98	61
Call for help	7	41	90	203	**520**
Cook meals	**393**	198	135	72	63
Guard home	80	103	**530**	103	45
Automate home	36	70	**420**	203	132

Figure 3: Chart summarizing the responses to each question in the comfort category.

Figure 4 is a chart summarizes the responses to each question in the cost category. As before, each task on the left represents a currently or potentially available robot that the participant was asked to consider. For each robot, the participant selected the price at which he or she would comfortably buy it. The responses range from low (would comfortably buy at a generally cheap cost) to very high (would comfortably buy at a generally expensive cost), with the additional option WNB (Would Not Buy).

Tasks:	WNB	Low	Med	High	Very high
Clean floors	273	**480**	86	19	3
Mow lawn	303	**403**	90	60	5
Organize medicine	**289**	240	228	83	21
Tell news and weather	185	**480**	74	86	36
Converse intelligently	**560**	79	90	76	56
Call for help	99	230	**409**	78	45
Cook meals	**630**	94	82	49	6
Guard home	60	**558**	201	30	12
Automate home	**424**	109	230	74	24

Figure 4: Chart summarizing the responses to each question in the cost category.

In examining these charts, the most trusted and well-received robots should score high on the comfort scale and high on the cost scale. Considering all-around utility, a robot that people are generally very comfortable with and willing to buy at a high price would be most promising.

To this end, the robot that calls for help would be well received; it has high ratings in comfort and a larger number of people willing to purchase it. Another robot worthy of consideration is the robot that guards the home. Although it did not score highly in comfort, it also shared a large number of people willing to purchase it, where most other robots had higher totals in the Would Not Buy category. In contrast, the robot that tells the news and weather holds high comfort ratings but a smaller number of people willing to buy it.

4.2: Pair-wise Comparison Analysis

The pair-wise comparison analysis is a two-step process, as briefly described in section 3.5. The data from two survey questions are compared for each iteration. The first step, Isolated Comparison, involves examining the data that may be ascertained using only the data from these two graphs. Any patterns or relationships that can be identified between the two sets of data are discussed. The second step, Overall Analysis, involves taking this additional information and relating it to the rest of the findings.

The first four comparisons examine one robot at a time, looking at the comfort and cost values of each. Conclusions are drawn based on the values themselves and the tasks performed by the robot.

The final four comparisons examine two robots at a time, looking at either comfort or cost. This pair-wise comparison allows for a more detailed analysis of the factors that may be responsible for similar or differing patterns between robots and their tasks.

At the end of the pair-wise comparison process, a final summarization is conducted to combine the gleaned information from all comparisons and discover any significant patterns.

4.2.1: Comparison of Comfort vs. Cost (Cleaning Robot)

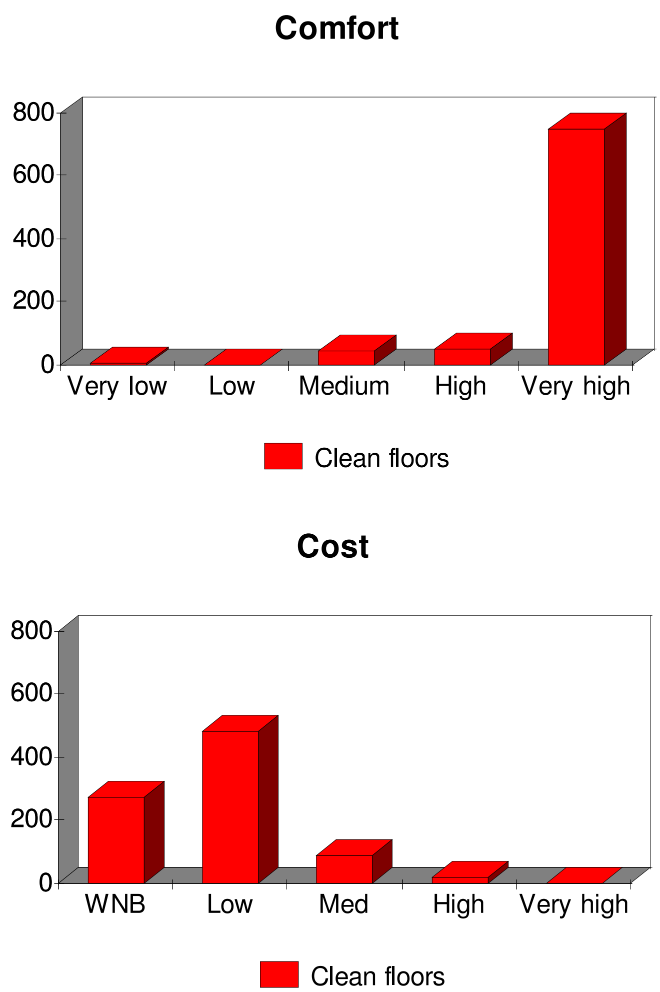
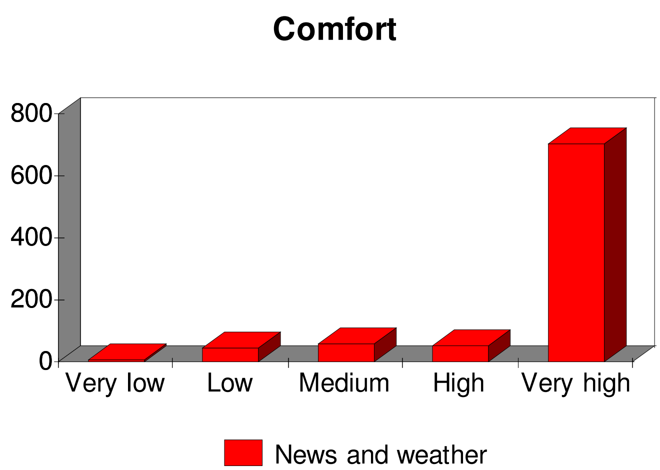


Figure 5: Comfort vs. Cost responses for the cleaning robot.

Isolated Comparison: Although a great number of participants were very comfortable with the floor-cleaning robot, most were either unwilling to buy it or only willing to buy it at a low price.

Overall Analysis: Compared to the rest of the robots, floor-cleaning is the task that most are comfortable with. The simple, generally non-invasive aspect of the robot lends to its high comfort rating, but its simple, limited use results in a lower demand and price.

4.2.2: Comparison of Comfort vs. Cost (News and Weather Robot)



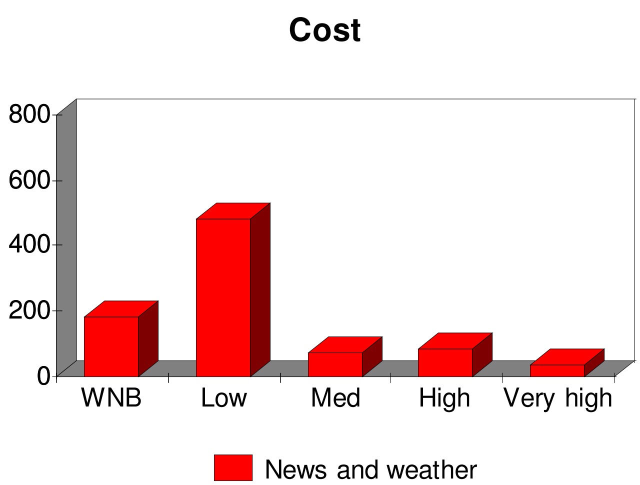
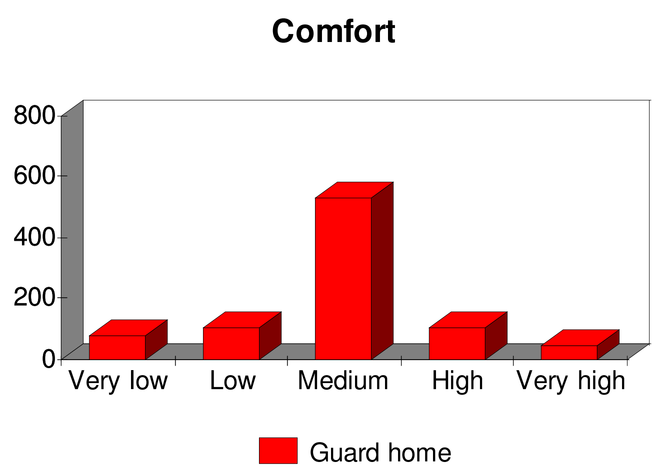


Figure 6: Comfort vs. Cost responses for the news and weather robot.

Isolated Comparison: Most are very comfortable with the news and weather telling robot. However, the price at which people are willing to buy it is low. Despite the fact that people are willing to spend so little for this robot, 78.5% are willing to purchase it.

Overall Analysis: These graphs follow the same pattern as the floor-cleaning robot, which is not surprising given that both robots are available today. Although most are still willing to purchase them both, the majority select the lowest price possible.

4.2.3: Comparison of Comfort vs. Cost (Guard Robot)



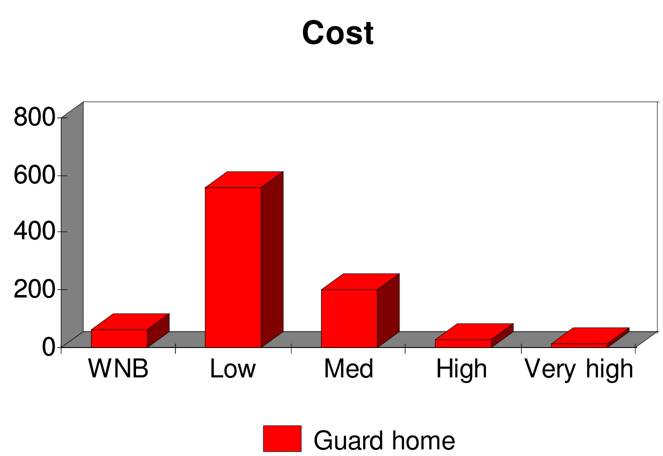


Figure 7: Comfort vs. Cost responses for the guard robot.

Isolated Comparison: The home-guarding robot rests at an average comfort rating, with most participants feeling neither very comfortable or uncomfortable. Despite this, 93% of participants are willing to purchase it. Although people are not willing to spend much on it, there are few that would not purchase it at all, suggesting that the utility of this robot outweighs comfort.

Overall Analysis: Deviating from the pattern set by the first two robots, the home-guarding robot only shares their low cost rating. This robot lacks the high comfort ratings of the former two, which may be a result of the fact that it is not a companion robot, but more of a sentry or alarm system with which the user does not directly interact. This nature has granted it a modal comfort value of medium, suggesting no significant discomfort or comfort.

4.2.4: Comparison of Comfort vs. Cost (Emergency Robot)

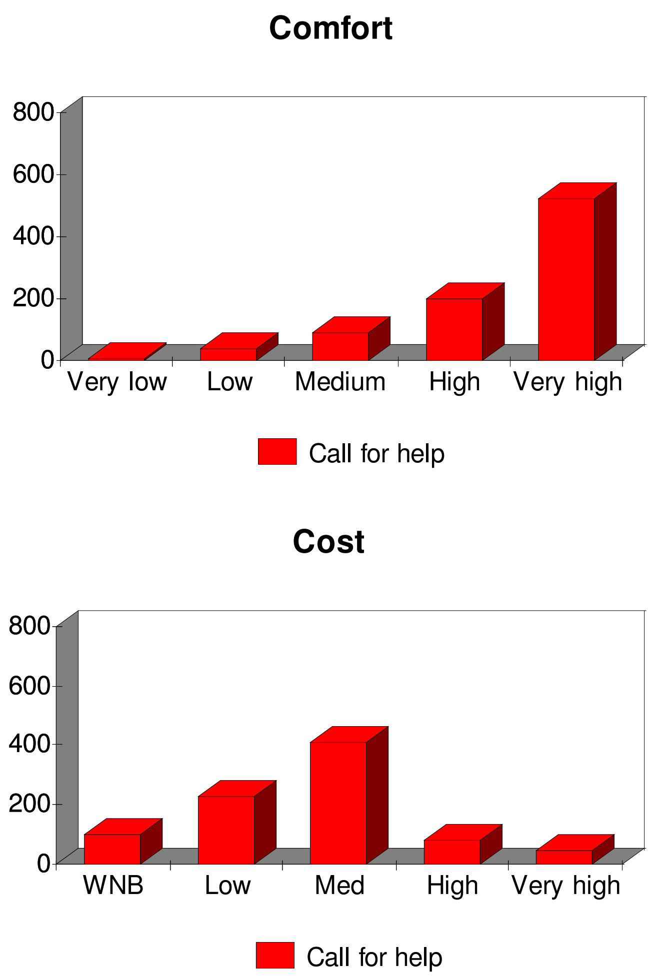
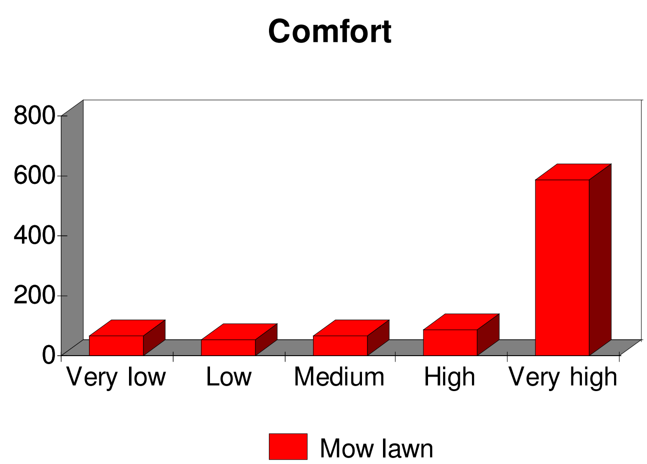


Figure 8: Comfort vs. Cost responses for the emergency robot.

Isolated Comparison: With a strong comfort and a medium cost rating, the help-seeking robot enjoys the most correlation between the two, in that a high comfort rating suggests a higher cost rating. Most survey participants were willing to purchase it at a medium cost, giving a greater value to its function. The appearance of the cost graph may be misleading; although there are few people willing to purchase it at a high or very high cost, it still holds the highest cost rating of all robots with a high medium value.

Overall Analysis: One of the most well-received robots on the list, the help-seeking robot is popular and received the highest possible cost ratings of all other robots; not only were people willing to buy it, but they were willing to buy it at a higher cost than the minimum, a pattern that serves as an example of a possible correlation between comfort and cost.

4.2.5: Comparison of Comfort (Lawn Robot vs. Conversation Robot)



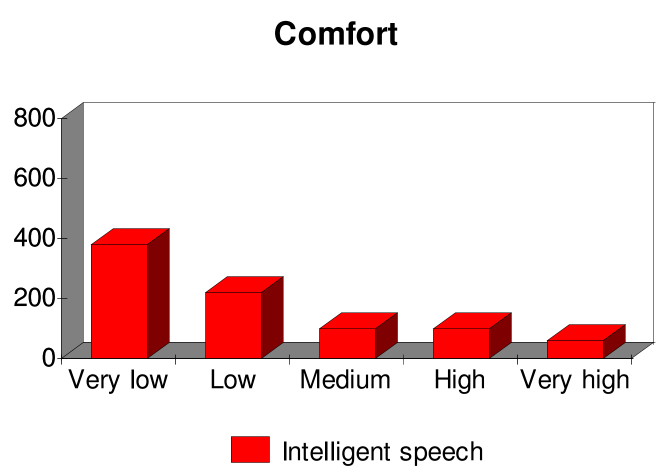
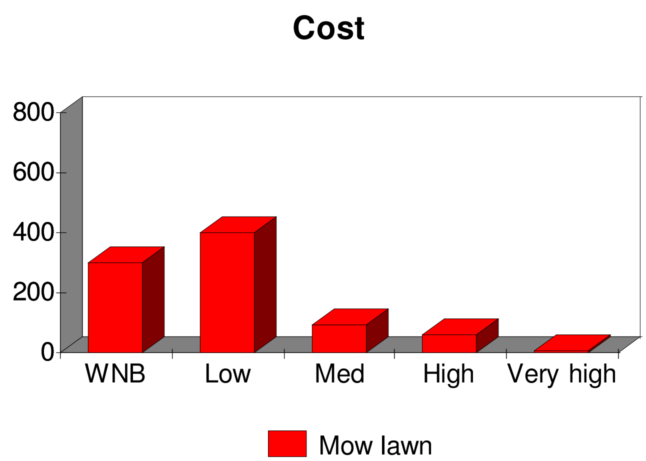


Figure 9: Comparison of comfort responses between the lawn robot and the conversation robot.

Isolated Comparison: Survey participants found the lawn mowing robot much more comfortable than the intelligent conversation robot. More people are able to relegate a simple, single-minded task to a robot than rely on them to serve a complicated function such as companionship.

Overall Analysis: Both of these comfort graphs follow the patterns set by the others; robots that perform less-complicated and socially involved tasks are easier to be comfortable around, whereas a highly intelligent and complex task is not as well-received. For example, the first two robots examined (cleaning robot and news and weather robot) both involve simple tasks and enjoy higher comfort ratings. This is in contrast to a more complex, involved task such as the one adopted by the cooking robot. It involves a much higher level of intelligence and intricacy than the other robots and was not as well received.

4.2.6: Comparison of Cost (Lawn Robot vs. Conversation Robot)



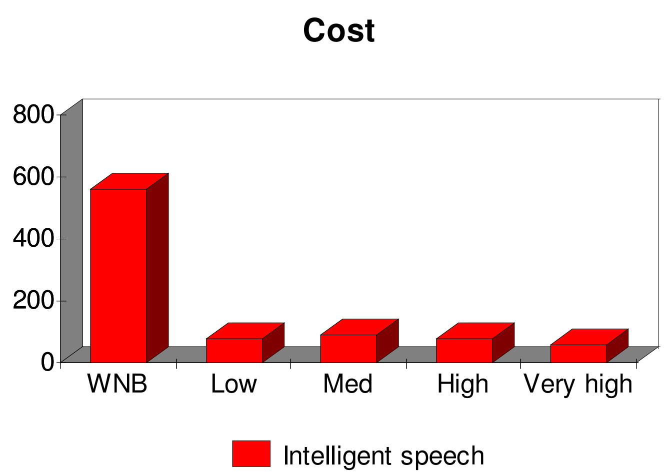
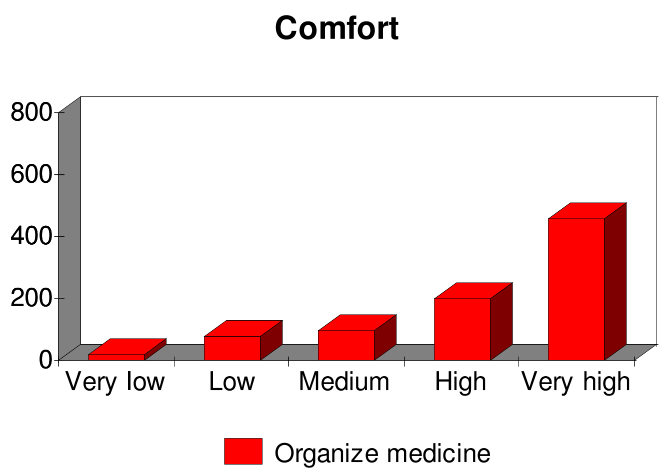


Figure 10: Comparison of cost responses between the lawn mowing robot and the conversing robot.

Isolated Comparison: Survey participants were more willing to spend money on lawn mowing than intelligent conversation. The luxury of a simulated friend may not offer as much incentive as the removal of a household chore.

Overall Analysis: This comparison further supports the possible comfort-cost correlation. The intelligent speech robot is the first one to have such abysmal cost ratings: few people are willing to purchase it. It exhibits technology unfamiliar or unknown to most and holds mostly entertainment value only; these two factors damage its capacity for popularity.

4.2.7: Comparison of Comfort (Medicine Robot vs. Cooking Robot)



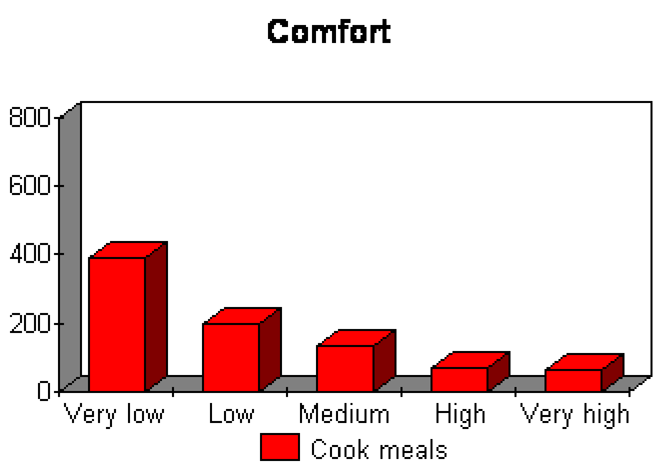
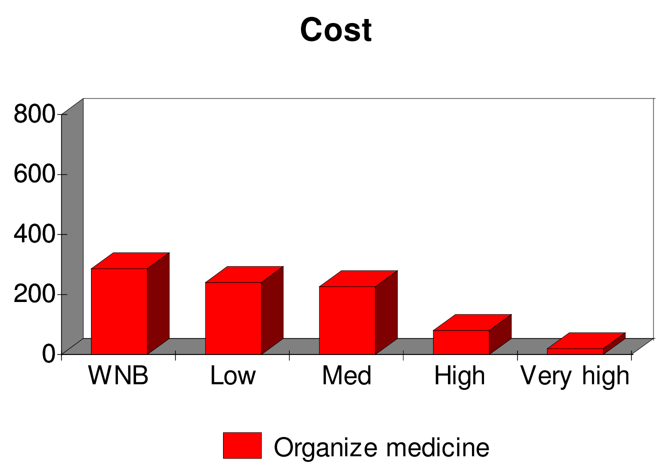


Figure 11: Comparison of comfort responses between the medicine robot and the cooking robot.

Isolated Comparison: The graph for the medicine-organizing robot displays a steady incline, whereas the graph for the meal-cooking robot displays a steady decline. This follows the examples of previous robots; medicine-organization is a task that people can attribute to robots more easily than cooking.

Overall Analysis: These graphs continue the trend supported by the last comfort comparison. Participants were more comfortable relegating a simple and easily understood task rather than an extremely elaborate and complex task.

4.2.8: Comparison of Cost (Medicine Robot vs. Cooking Robot)



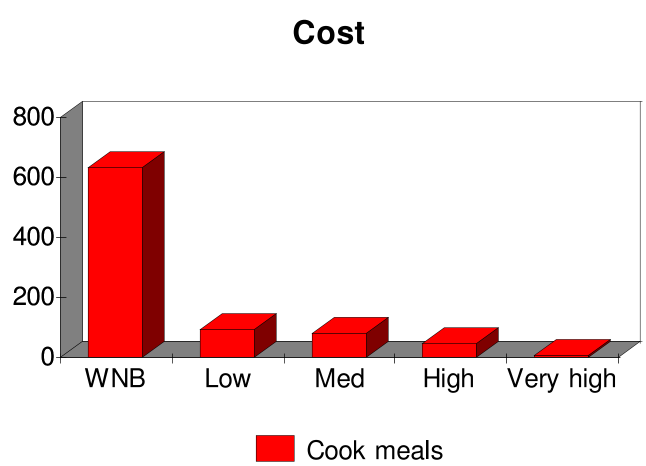


Figure 12: Comparison of cost responses between the medicine robot and the cooking robot.

Isolated Comparison: Few people were willing to purchase the meal-cooking robot, whereas more people were willing to try the medicine-dispensing robot. The difference is significant: twice as many people were unwilling to pay for automatic food preparation over medicine organization.

Overall Analysis: This final comparison yet again supports the notion of the ease in assigning simpler tasks to robots. The complexity of the meal-cooking robot is similar to the intelligent speech robot, the fact of which supports their similar graphs.

4.2.9: Final Summarization

By the end of the set of pair-wise comparisons, two patterns become evident. The first is that, with few exceptions, a higher comfort rating (people are more comfortable with using the robot) suggests a higher cost rating (people are willing to buy it for more), and vice versa. Based on the survey responses, the more comfortable a person is with a particular robot, the more willing he or she will be in purchasing it and the more they will be willing to pay.

The most significant exception to this rule was the home-guarding robot. However, this exception may be a result of the second pattern: comfort and cost are both functions of the importance and relevance of the robot's task. A robot with a useful, beneficial task that goes beyond entertainment value and serves to provide safety or reduce work tends to have higher comfort and cost ratings. Moreover, a robot with a complex, human-like task that is difficult to relegate to a machine is not as well-received in either category.

Exemplifying this pattern are the robots that converse intelligently and cook meals. Both are actions that are normally attributed to humans and are nigh-impossible tasks for a robot using today's technology. This sense of unknown or foreign technology seems to hinder the acknowledgement of the robot's potential in the household. Combined with the fact that there is low demand for the replacement of these tasks, the two robots suffer from low comfort and cost ratings.

In-depth analyses based on the interviews are performed in section 4.4, for three of the survey robot tasks. This provides a personalized look at these robots.

4.3: Rank-Correlation Analysis

Spearman's Rank-Correlation Coefficient is a statistical analysis method that helps reveal the relationship between two variables. Each robot in this study has been examined using two variables: how comfortable people would be with them and how much people are willing to pay for them. The hypothesis driving the study is predicting a strong correlation between the two: the more comfortable people are with a robot, the more they are willing to pay.

Because Spearman's method uses two variables, the comfort and cost values for each robot have been condensed into a single rating. This is obtained by summarizing the survey results into a single number for analysis. For example, below are the survey results for the robot that cleans floors (using comfort):

	1	2	3	4	5
Clean floors	9	3	45	52	752

Figure 13: Chart summarizing the responses to the cleaning floors robot in the comfort category.

To obtain the comfort rating for this robot, these numbers are added together, using their comfort score as a multiplier. This is done as follows:

$$1(\mathbf{9}) + 2(\mathbf{3}) + 3(\mathbf{45}) + 4(\mathbf{52}) + 5(\mathbf{752}) = \mathbf{4118} \text{ comfort rating}$$

This method is applied to each robot to obtain ratings for both comfort and cost. Below are the ratings for each robot, ranked in ascending order:

	Comfort Rating
Cook meals	1797
Converse intelligently	1823
Guard home	2513
Automate home	2908
Organize medicine	3587
Mow lawn	3657
Call for help	3771
Tell news and weather	3985
Clean floors	4118

	Cost Rating
Cook meals	1290
Converse intelligently	1572
Clean floors	1582
Mow lawn	1644
Automate home	1748
Organize medicine	1890
Tell news and weather	1891
Guard home	1959
Call for help	2323

Figure 14: Chart listing the comfort and cost ratings for each robot in ascending order.

The equation behind Spearman's method is the following:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

Figure 15: Spearman's Rank-Correlation coefficient equation.

The variable ρ is the correlation value. It ranges from -1 (least correlation) to 1 (most correlation). The variable n stands for the number of variable pairs being compared. The variable d_i represents the difference between each variable.

Using Spearman's method, a new table is constructed which ranks each robot by its ratings and determines their differences:

	Comfort Rank	Cost Rank	d	d^2
Clean floors	1	7	6	36
Tell news and weather	2	3	1	1
Call for help	3	1	2	4
Mow lawn	4	6	2	4
Organize medicine	5	4	1	1
Automate home	6	5	1	1
Guard home	7	2	5	25
Converse intelligently	8	8	0	0
Cook meals	9	9	0	0

Figure 16: Spearman's method applied to the survey data.

These difference values are then substituted into the equation to obtain a ρ value of 0.4. The ρ value is then compared to the critical value for this data set.

The critical value is dependent on the number of variable pairs being evaluated. In this case, nine robots make nine different pairs. The critical value is then obtained by looking up the value in a significance chart. The following table displays sample critical values for different values of *n* (using a significance level of 0.05, or a 5% chance that the correlation was achieved by chance):

N	Critical Value
5	1
6	0.886
7	0.786
8	0.738
9	**0.683**
10	0.648
12	0.591
14	0.544
16	0.506

Figure 17: Table of sample critical values for use in Spearman's method (Tett, 2003).

In this case, the critical value is 0.683. This means that a ρ value's absolute value needs to exceed this critical value in order to imply a significant correlation. Because the data collected yields a ρ value of 0.4, this data set is not significantly correlated.

In order to determine the validity of this claim, a test using the data set's degree of freedom is performed. In Spearman's method, the degree of freedom is equal to the number of variable pairs minus 2. Thus, the degree of freedom for this set of data is 7. This is now used to test the significance of the ρ value. The following chart shows the significance of a data set correlation using both the ρ value and the degree of freedom.

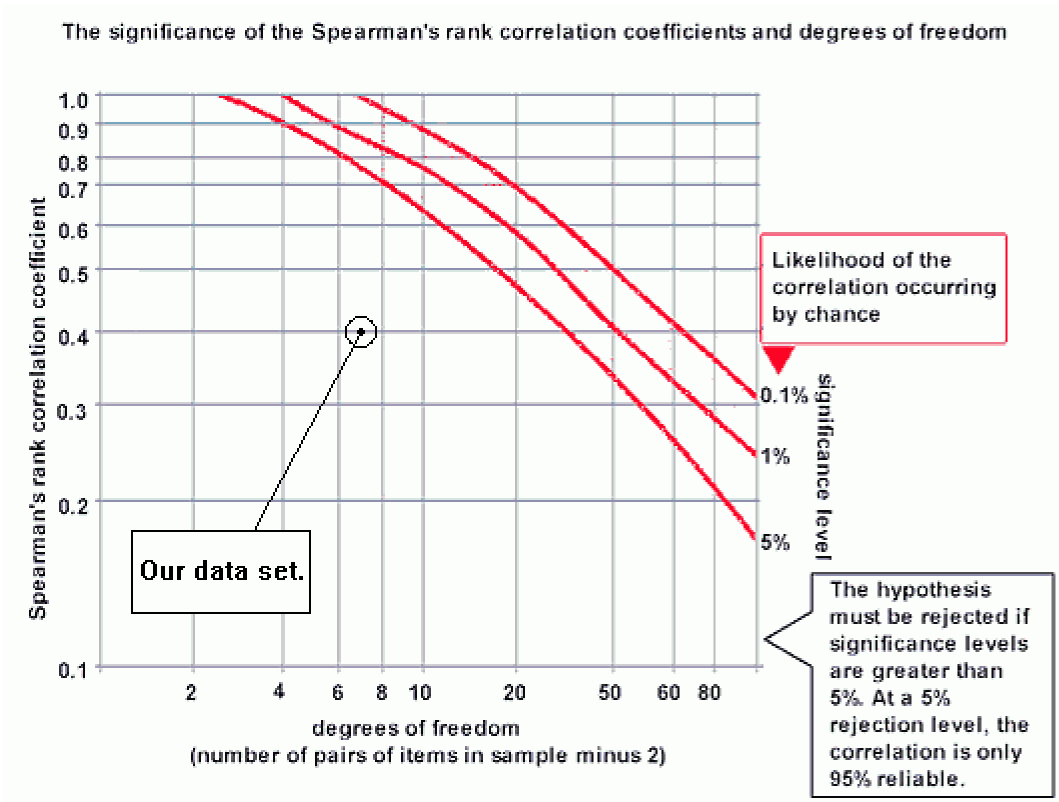


Figure 18: Chart showing significance using degrees of freedom (geography fieldwork.com).

At a degree of freedom of 7 and a correlation coefficient of 0.4, the data set does not reach any of the main significance levels. Using the statistics software available at Wessa, the significance level of this set of data is 25.4% (www.wessa.net). This means that there is a 25.4% that the correlation between comfort and cost occurred by chance. Although there may be some relationship between the two variables, it is not substantial enough to show a true connection.

4.4: Interview Examination

As explained in section 3.6, the interview portion of data collection involved conversations with seven people, five experts and two non-experts, in order to gain a greater understanding of the thinking and reasoning behind survey responses. They were each selected based on their prior experience and current technological prowess to provide a varied outlook on these robots.

Each participant was asked to give their general impressions of robotics, as well as their responses to three sets of interview questions, dealing with the robot that tells the news and weather, the robot that cooks meals, and the robot that automates the home.

The news and weather robot was described as a small, desktop robot that connects to the internet through your computer. It is able to read internet news articles and give weather reports using a digitized voice. Likewise, it is activated by voice command.

The robot that cooks meals was described as a humanoid companion that has familiarized itself with the layout of the kitchen and is able to intelligently prepare and serve meals. The owner communicates with the robot using voice commands, and it is intelligent enough to keep the kitchen clean and cook safe meals.

The robot that automates the home was described as a full-home system that monitors each room in the house using cameras and recording devices. In this manner, the owner is able to turn on and manipulate appliances with the use of gestures and voice commands. For example, the owner may change the setting of the thermostat by saying, "Set temperature to 72 degrees," or turn on the television by pointing at the screen.

4.4.1: Interview with George Grivaki

George Grivaki is a young adult in college that has started using computers only recently. Generally inexperienced with most electronics, Grivaki used to believe that computers were "unwieldy and unnecessary." However, his impressions have changed in the past few months. After obtaining a personal computer, Grivaki has transformed his views, stating "the technology used is fascinating. It goes beyond my expectations." When asked about robots, Grivaki was not held back by his previous convictions. "After seeing the convenience of my computer, I can only imagine the possibilities of robots in the home. I am very excited," stated Grivaki.

Grivaki was excited by the prospect of a robot that tells the news and weather, but was unwilling to purchase one. "It sounds like a lot of fun, but I don't have much use for it," stated Grivaki. "I wouldn't mind checking the news station or the newspaper at my own leisure." However, Grivaki was more motivated in his response for the robot that cooks meals. "I would definitely purchase a robot like this. $1,000 seems appropriate for me. Although it would probably be worth more, I wouldn't spend more money on a luxury."

Regardless of his comfort with these robots, Grivaki was not comfortable with the concept of home automation. "I don't need a robot to monitor my life. I would feel as if I were not a part of my own home."

Grivaki represents the typical survey participant. Although more willing to purchase the cooking robot than most, Grivaki does not break the pattern given by the survey results.

4.4.2: Interview with Kiki Kouvaris

Kiki Kouvaris is an elderly woman living in Greece that uses few electronics in her home. She finds comfort in performing daily chores and activities on her own. Her interview responses have been translated from Greek to English for this report.

As expected from someone who is not a part of the technological community, Kouvaris finds electronics to be “unnecessary and difficult to use or learn.” The idea of even one robot in her home is unsettling; Kouvaris describes most of the sample robots from the survey as “toys for the younger generation.”

When asked about the robot that tells the news and weather, Kouvaris was not impressed. “I do not want to rely on a machine to tell me what it wants me to hear. I want to find out the news for myself,” stated Kouvaris. Similarly, Kouvaris dismissed the idea of the cooking robot entirely, stating “I find joy in cooking. Having a machine take this away would not be a convenience, it would be a crime.”

Kouvaris was attracted by the home automation robot. She described a possible scenario, saying, “I would not mind being able to control my home without reaching for things or struggling to understand controls.” Kouvaris followed by saying, “as long as I can use it easily, I would not mind it, but I would not spend any of my money on it.”

Kouvaris is unwilling to purchase any of the robots, something also generally suggested by the survey results. However, she finds herself comfortable with only a small portion of the available robots; namely, those that help with safety or enhance what she can already do in the home. She is afraid of “a lack of control,” but the few robots that still let her make the decisions are seen as bearable by her.

4.4.3: Interview with Kenneth Stafford

Kenneth Stafford, the Director of Robotics at Worcester Polytechnic Institute, finds himself already comfortable with the concept of robots in the home. Experienced with the modern advances of the robotics industry and the projects in development, Stafford sees promise in the growth of household robot popularity.

Upon reviewing the robot that tells the news and weather, Stafford stated that it “would be a convenience” and holds “major appeal,” but the usability of the robot compared to current venues would restrict its popularity. “It’s not as valuable to me,” stated Stafford. Willing to purchase it at $100, the ability to quickly check the desired news and weather online reduces the value of this robot.

The idea of a robot cook intrigued Stafford, who stated that he “could see that happening.” He understands that social interaction is important in realizing the potential of such a robot, but he finds “no concerns socially” for himself. One issue raised by Stafford was the impact the robot would have on the home. He asked about a potential problem that may be caused if the robot began “changing the layout” of the home to accommodate its designs. However, Stafford would purchase the robot at around $1,000, finding the help “very useful.”

Likewise, Stafford found himself comfortable with the home automation robot, yet feels others might not be as easily pleased. “I would be receptive,” stated Stafford, “although my wife would be bothered.” He discussed the additional potential of “electronic robot slippers” or a “smart controller” to help operate the robot. Within discussion, Stafford identified the robot as one that should remain “not very expensive,” agreeing to settle for $300 to $400 for the robot in his own home.

Stafford represents the most optimistic of users; his personal experience with robotics give him a positive outlook, as he is willing to purchase all three of the robots: telling the news and weather, cooking meals, and automating the home. However, even given this optimism, Stafford follows the same pattern developed by the survey participants: he agreed with the general amount to spend on each robot.

4.4.4: Interview with Brad Miller

Brad Miller, the Associate Director of Robotics at Worcester Polytechnic Institute, reaches a similar understanding of the robot industry as Kenneth Stafford. Miller owns household robotics of his own, so his personal experience influences his opinions.

The robot that tells news and weather is seen as comfortable by Miller, but he is unwilling to purchase it, instead willing to rely on “Google News or other online sources” for his information. However, the robot that cooks meals provides a different scenario. “It depends on how it works because it is difficult to gauge service,” stated Miller. Although he would not purchase this robot either, he found the concept intriguing and convenient. Lifespan raises one concern; Miller would want the robot to last for “at least five years” reliably.

The home automation robot was the only one Miller was willing to purchase, at around “a couple thousand.” Although he is comfortable with the idea, he feels “privacy would be a concern to most.” As with the cooking robot, Miller would want it to be "working flawlessly" before purchase. Miller shares his robot comfort with Kenneth Stafford, yet is selective in his purchasing selections. To Miller, the task it performs "is just as important as the cost of creating the robot itself," as a cheap robot that doesn't provide much is still not worth it.

4.4.5: Interview with Robert Lindeman

An Assistant Professor at Worcester Polytechnic Institute, Robert Lindeman is attracted by electronics and robotics of all kinds. Knowledgeable about current developments, Lindeman keeps himself informed about robots on the horizon.

Despite the potential use of the robot that tells the news and weather, Lindeman sees it as a "mere luxury," overshadowed by the success of internet databases and the convenience of the newspaper. Regardless, he is willing to spend $100 on the robot as a novelty. He found more interest in the cooking robot, being willing to "try it out" yet "less inclined to purchase it." Although Lindeman would not mind the convenience, he stated that the robot would be "best suited for those with a sedentary life."

The robot that automates the home was the most promising to Lindeman, who had already learned about current models and design. Unwilling to spend the money for the additional convenience, Lindeman did find it "useful and engaging," yet warned "its ability to perceive is what defines its success as a device."

Following the trend of his fellow professors, Lindeman is comfortable with all three robots, but is only willing to purchase one due to its low cost. His comments support the need for a robot to be both appropriately priced for most consumers and effective in the household.

4.4.6: Interview with Michael Ciaraldi

As a Professor of Practice at Worcester Polytechnic Institute, Michael Ciaraldi has had a great deal of exposure to the electronics and robotics industry, having read about many recent developments and possible innovations. His opinions are backed by personal experience, as Ciaraldi has much of his home already wired for home automation.

Following the trend set by his fellow interviewees and the survey results, Ciaraldi was also comfortable with the news and weather robot but would be unwilling to buy it, saying that it requires "faith in the computer to decide what you want." Although Ciaraldi finds the robot as potentially useful, he would "prefer to be in control." Additionally, he suggested that "limited exposure in the field" would stunt its popularity.

The robot that cooks meals prompted Ciaraldi to discuss its social implications. "Cooking meals can serve as a family dynamic that isn't easily replaced," stated Ciaraldi, adding, "I wouldn't mind using it, but it still raises the issue of trust." He further questioned, "would it be able to adapt and correctly identify ingredients, depending on its environment?" These questions raise important factors in determining how comfortable people would be with such a robot, as the potential for error, especially in something as sensitive as cooking, can introduce serious concerns. Estimating the price of a robot at between $5,000 and $10,000 in today's dollars, Ciaraldi would be willing to purchase it at around $1,000, once the technology for this robot's task became more easily available.

The home automation robot provided Ciaraldi with the opportunity to expand on his own personal experience. He has enjoyed the convenience of automatic lights and remote appliance control for two years, expanding on his current setup with his own recommendations. “What if you were able to control your home from the outside?” asks Ciaraldi. He mentions the possibility of cell phone coordination to further develop the idea of home automation. Naturally comfortable with the idea given his current involvement, Ciaraldi would estimate the appropriate cost for full home automation at approximately $1,000.

Both comfortable with and knowledgeable about robotics, Ciaraldi’s professional opinion coincides with the patterns revealed by the survey information. His own ideas help define what is important in successful robotic design.

4.4.7: Interview with Fredrik Linaker

Fredrik Linaker, researcher at Accenture Technology Labs, has contributed to many publications, with topics ranging from autonomous systems to artificial intelligence. His work in the robotics industry helps support his professional opinion of household robots and the future of the industry.

When discussing the robot that tells the news and weather, Linaker was uninterested, stating that he would “prefer to use my keyboard as input as it’s faster, more reliable and less of a distraction to people around me.” Having tried a similar robot, Linaker found it “a bit of a nuisance” and would be unwilling to purchase it.

When it came to the robot that cooks meals, Linaker found the prospect more promising, being willing to own one, “given that it performs reliably and the resulting food is reasonable.” He would be willing to pay a maximum of $500, “only after seeing it in action a couple of times.”

The home automation robot was not as well received. Linaker suggested that reliability was an important factor, adding “the degree of automation needed in my home is not very high.” Unwilling to purchase the robot, Linaker desires a greater level of assurance about its capability.

With experience and understanding of household robotics, Linaker identifies multiple concerns that may influence their introduction into homes, including “mobility,” “identification,” “reliability,” “energy,” and “floor space problems” that can limit their potential if not addressed. The main factor in the growth of household robot popularity is dependent on the developers themselves; Linaker stated “roboticists have yet to figure out an attractive application for the mass market. While it is easy to imagine the robots doing the sorts of jobs that maids do today, this is probably not the whole story.” Despite these issues, Linaker feels that “robots for entertainment and companionship will become more prevalent,” yet the most useful of household robots “are not likely in the next five years.”

5. Conclusion

The results of the pair-wise comparison analysis, Rank-Correlation coefficient method, and the interview examination suggest that the concept of household robots will take some time to settle into today's culture. Although many ideas and concepts for robots are in circulation, current technology does not allow for the creation of the most helpful or beneficial robots. Most of the robots released today serve as minor entertainment or perform minor chores.

As suggested by Fredrik Linaker, the next step is to determine an "attractive application" for household robots. The robots that were well-received in the survey performed tasks that people were willing to relegate to machines. Performing advanced, highly-intelligent tasks such as holding a conversation or cooking a meal is difficult to imagine and thus less popular by today's standards.

Based on the survey results and analysis, there are specific types of robots that people are most comfortable with. The top three (cleaning floors, telling the news and weather, and calling for help) are generally simple in comparison to the other robots proposed. This suggests that most people are not ready for more complex innovations but are more comfortable with current robots. As suggested by both Linaker and Angle, skepticism and trust are hurdles that must be overcome alongside technological advancements.

The statistical analysis performed using Spearman's Rank-Correlation coefficient method shows that there is no direct link between comfort and cost that can be made with this data set. However, this is but one step in determining how to make robots more socially acceptable. Linaker observes that comfort is one of the most important aspects to be considered for the creation of family-oriented robots. To this end, roboticists must focus on not only the technological capabilities of a robot, but also the aspect of making them socially acceptable.

All interviewed experts agree: household robots will eventually become prevalent in society. The question that remains is when. Both limited technology and a low demand for robots to replace household tasks hold back the advancement of household robots. As the industry expands in both of these scopes, it will be much easier to introduce them into the household for more than entertainment purposes.

This question is further clouded by the variance in robot sales. Revenues from home robots by iRobot have declined, whereas revenues from military robots have increased (Jethanandani, 2007). Different types of robots are yielding mixed receptions; the direction that sales will take for household robots is difficult to map. However, if popularity for current robots continues its slow climb, it may allow for the acceptance of more complex task-oriented robots in the home.

With the invention of new robots and the continued advancement of current robots and artificial intelligence, their role in our society will slowly yet inevitably grow. Once these desired household tasks are identified and explored by roboticists, the realm of household robotics will have ample room to expand and evolve.

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