Social Acceptance of Nanomedicine

AN INTERACTIVE QUALIFYING PROJECT

submitted to the Faculty of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

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Date: March 1, 2007

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ABSTRACT

The social acceptance of nanomedicine was studied through a survey distributed to Worcester Polytechnic Institute students. There was no correlation between the acceptance of nanomedicine and the respondents' cognitive types or their risk behavior. Nonetheless, a significant result for public-relations strategies of nanomedicine was that the most influential factors for using a new medicine were: doctor's advice, clinical research, side effects, FDA approval of the medicine, information on package, and research journal.

TABLE OF CONTENTS

TABLE OF FIGURES

1. CONTEXT AND GOALS

1.1. INTRODUCTION

The improvement of the quality of life in our society over the last few decades has been very closely related to the rapid development of technology. Many organizations use technological advance as the main criterion to judge the progress of the economy, thus determining the quality of people's lives in different geographical regions. Nanotechnology is undoubtedly the newest and the most promising field of engineering applications in the western countries. Intense academic research over the last years coupled with industrial demand is making it possible for engineers to measure, observe, control, manipulate, and manufacture devices with dimensions between one and one-hundred nanometers. These new techniques have the potential to radically revolutionize the way we fabricate and use new products.

1.2. NANOTECHNOLOGY: TODAY'S EMERGING TECHNOLOGY

However, as with all new technologies, nanotechnology contains an attendant risk. This risk factor has an immense influence on consumers' mindsets, especially on their receptivity to nanomedicine, which is one of the areas of nanotechnology. The potential benefits of nanotechnology and nanomedicine cannot be fully studied without proper acceptance and funding from the scientific community and beyond. Therefore, a careful investigation is essential for understanding how people perceive the risks of these new fields and what can be done to change people's decision-making processes.

In 1959 the Nobel laureate physicist Richard Feynman presented a lecture which he entitled, "*There's Plenty of Room at the Bottom.*" His ideas challenged the scientific community to think critically about unforeseen scientific discoveries and their potential applications. He believed that careful application of the laws of physics and chemistry would make it possible for engineers to design and manufacture devices with a technique that is today referred to as the "bottom-up"[1] technique.

This new approach would construct materials and devices molecule by molecule, giving us the ability of molecular manufacturing. The process would create new products

[1] Editors of *Scientific American*, Understanding Nanotechnology, New York: Warner Books, 2002.

by stacking molecules one by one and leaving no space for errors. In theory, with the bottom-up method, every entity that is built today could be reproduced by using standardized molecular manufacturing techniques[2].

Figure 1: Artist's impression of nanomedicine device[3]

The essential tool that will make molecular manufacturing possible is the assembler. An assembler is a device, like the milling machine and the lathe, which can construct products; it will be the quantum of manufacturing[4]. The existence of these assemblers will produce molecular devices with optimal accuracy. Furthermore, their use will reduce costs drastically since there is almost no need for human control as with current machinery. More importantly, toxic leftovers and polluters will be eliminated from the manufacturing process as assemblers create products from molecules.[5]

Another approach for nanotechnology is termed self-assembly. It is well known that many molecules have a tendency to bind with each other because of their chemical affinities[6]. It is also known that some structures are more stable than others. If the appropriate molecules are positioned correctly they will self-assemble similarly to a natural process.

[2] Ratner,M. and Ratner D. Nanotechnology: A Gentle Introduction to the Next Big Idea. New Jersey: Prentice Hall, 2003.
[3] Picture taken from: http://pnewsimg.bbc.co.uk.
[4] Editors of *Scientific American*, Understanding Nanotechnology, New York: Warner Books, 2002
[5] Ibid.
[6] Ratner,M. and Ratner D. Nanotechnology: A Gentle Introduction to the Next Big Idea. New Jersey: Prentice Hall, 2003.

These techniques have had a major impact in the way scientists and engineers think about future innovations. Nanotechnology promises a great future, not only in the way we create new applications, but also in the way we think about these revolutionary applications. This field has the potential to become the grand unifier of the applied sciences. From materials science to biomedical engineering, almost every industrial area will be affected by the applications of this new field. As a matter of fact, many companies are currently using nanodevices: IBM has a data storage device; Gilead Sciences has a drug delivery system[7]; Carbon Nanotechnologies has the best available technique for manufacturing raw materials, especially buckminsterfullerenes[8]. In the year 2000, under the Clinton administration, the United States government dedicated itself to the development of nanotechnology when the National Nanotechnology Initiative was created with a budget of $422 million[9]. Since then, funding and interest for research has increased enormously. In 2001 more than thirty nanotechnology research groups and centers were active in the field[10]. Nanotechnology has the potential for applications in various fields such as: national security, medicine, clothing, and the food industry. Furthermore, the spatial dimensions make this field suitable for the synthesis of most organic compounds. Hence, the development of nanotechnology will inevitably bring major advances in medicine and biology.

1.3. NANOMEDICINE

In fact, the application of nanotechnology to medicine is so broad that this new field has been given a term of its own. Nanomedicine aims at achieving medical benefits using nanotechnological applications through nanovaccinology, nanoparticle drug therapy, and biosensors. Applications in this area will make it possible to repair and improve biological systems at the molecular level, as well as monitor biological activities. These tasks will be accomplished through the sub-areas of nanoparticle drug delivery, nanodiagnostics, and molecular nanotechnology.

Nanotechnology can start a true revolution in biomedical applications. New types of drugs and new drug-delivery techniques have already been designed. Photodynamic

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[7] Editors of *Scientific American*, Understanding Nanotechnology, New York: Warner Books, 2002.
[8] Ibid.
[9] Ibid.
[10] Ibid.

therapy brings an incredible change in treatments of many diseases by attacking them with greater specificity and accuracy[11]. This therapy is an alternative technique for treating cancer that does not present the deteriorating side effects that are caused by chemotherapy[12].

Another revolution with remarkable applications is the molecular motor. These devices will make the transportation of drugs and sensors inside the body very efficient by delivering drugs to the specific nanoluminescent tagged cells[13]. Neuro-electronic interfaces will make possible the activation of receptors and synapses that have been disconnected from the brain. These nanodevices will be connected to computers in order to maintain and execute the functions that could not be performed by the damaged brain[14].

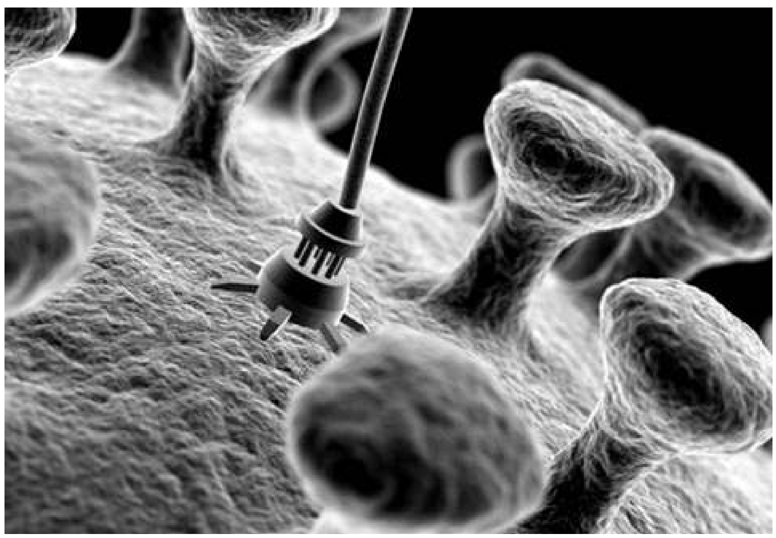

Figure 2: Artist's impression of nanomedicine device[15]

Sensors will play an essential role in the application of nanomedicine. The size of such structures will be optimal for medical uses. Biosensors open a whole new window in medical practices, changing not only the way we monitor diseases, but also the way we identify them. With these machines we can identify many different biological entities

[11] Ratner,M. and Ratner D. Nanotechnology: A Gentle Introduction to the Next Big Idea. New Jersey: Prentice Hall, 2003.
[12] Ibid.
[13] Ibid.
[14] Ibid.
[15] Picture taken from: www.nanotechnologyinvesting.usimagesnanotechnology-480.

starting from proteins and drugs and ending at complex organisms like viruses[16]. DNA sensing is a great tool in medical applications for identifying DNA sequences that are unique to a certain bacterium, virus, or genetic diseases. Nanoscientists have developed extremely accurate techniques for DNA sensing by designing small molecules that change color when they bind to a given DNA sequence. A different class of molecules has been used to design electronic noses, which are another type of sensor that function similarly to the human sense of smell[17].

Up to date, no mass production of any of the above products has been possible. However, intense research in some of the major labs in the world is showing that these products are not a mere hope, but can be built in the near future. Having no market history, the field of nanomedicine cannot be assessed as profitable or non-profitable. The initial success in the market will not only be determined by the effectiveness of the products, but also by the way the consumer perceives the product itself. The effectiveness of any device can be assessed through scientific analysis and laboratory testing, but the perceived risks can only be understood by studying the consumer's decision-making process.

1.4. PREVIOUS RESEARCH

In order to achieve this broadly defined goal, this project group investigated the existing literature about the human psyche─the process one uses when making a decision─and public-acceptance trends of prior technologies. Among the various theories that are presented about the processes that people use to form a decision, Dietram A. Scheufele and Bruce V. Lewenstein wrote an article entitled, "The public and nanotechnology: How citizens make sense of emerging technologies" that proved to be influential in our research. The authors referred to the Cognitive Miser versus Scientific Literacy theory[18]. Their research consisted of a phone survey of 704 consumers which gathered information about people's knowledge and attitudes of nanotechnology. The

[16] Ratner, M. and Ratner, D. Nanotechnology: A Gentle Introduction to the Next Big Idea. New Jersey: Prentice Hall, 2003.
[17] Ibid.
[18] Scheufele, Dietram A. and Lewenstein, Bruce V. "The public and nanotechnology: How citizens make sense of emerging technologies." Journal of Nanoparticle Research. Springer Inc. 2005.7: 659-661.

article also identified a key factor that influences how the public views nanotechnology and its risks and benefits—media framing[19].

Sheufele and Lewenstein's article discusses the theory of Cognitive Misers and Scientific Literates as the two existing groups that people fall under when making a decision[20]. Of the two groups, the majority of the public is classified as Cognitive Misers. Those who fall under the Cognitive Miser model are characterized as valuing the advice of friends and family and being highly influenced by the media's portrayal of a topic, as cognitive misers employ cognitive shortcuts referred to as heuristics[21]. Conversely, Scientific Literates value the process of gathering information when making a decision, regardless of the topic of interest. These individuals often reference research journals and colleagues or persons who are highly knowledgeable in the field. Scientific Literates make a decision after they believe enough information has been collected in the topic to formulate an educated conclusion[22].

For three successive years, teams of students have been conducting a semester and a half Interactive Qualifying Project[23] (IQP) on the topic of nanotechnology. The objective of the third-year IQP team was to build on the past two IQPs' research and conclusions. The first IQP focused on studying people's perceptions about the applications of nanotechnology in the fields of medicine, materials, and manufacturing[24]. The research showed that people's acceptance level for the applications of nanotechnology in medicine was low. They concluded that people's acceptance level correlated to how directly they were affected by the applications of each field.

Expanding on the first IQP's findings, the second IQP group researched three existing technologies and their historical trends of public acceptance to find a correlation with acceptance trends of nanotechnology[25]. The technologies studied showed three different levels of direct contact with the public: nuclear energy, which represented the least

[19] Ibid.
[20] Ibid.
[21] Ibid.
[22] Ibid.
[23] Commonly referred to as an IQP on the WPI campus, this project is a requirement for all students to graduate.
[24] Allwood, T., Psiakis, K., Regan, T. *WILL PREY CONSUME NANOTECHNOLOGY?* IQP 2005. Worcester Polytechnic Institute.
[25] Sklyar, A., Smith, J., Stedman II, C. *Social Acceptance of Technologies*. IQP 2006. Worcester Polytechnic Institute.

personal contact; genetically modified foods; and vaccination, which represented the most personal contact. Their research showed that the perception of risk vs. benefit was the most important factor in determining social acceptance of nanotechnology.

The conclusions from the first and second IQPs showed that nanomedicine was the least socially accepted area of nanotechnology and that a very important factor in determining its social acceptance was the perception of risk vs. benefit. These findings were the principal motivation for focusing this IQP on the public's social acceptance of nanomedicine with an emphasis on the perceived risk versus benefit.

1.5. PROJECT GOALS

As stated before, previous research has shown that people's decision-making process is not governed by merely one factor. A plethora of literature proposes that a variety of influential parameters exist in the decision-making process for accepting a technology. The two parameters of the decision-making process used in this study were the *Cognitive Miser vs. Scientific Literate Models* and the *risk behavior* of each individual. The primary goal of this IQP is to establish the most influential factors on the decision-making process for the use of nanomedicine, and secondly to determine the correlation between the stated parameters on the decision-making process and the acceptance of nanomedicine. A survey was collected from 250 WPI students to accomplish the primary goal of this IQP[26].

In accomplishing the primary goal of this project, we also study the individual's change of acceptance of nanomedicine in the survey. The results obtained from the individual's change of acceptance of nanomedicine can be correlated to each individual's data on the first two aspects of the decision-making process in order to determine their correlation.

Our research might prove beneficial to manufacturing technologists and investors in the field of nanomedicine. If nanomedicine specialists knew the key factors which people use when evaluating the potential risks and benefits of nanotechnology, their public relations techniques could be optimized. This task is of importance to not only manufacturing technologies and investors, but to the general public as well. It is

[26] See APPENDIX A for the survey.

necessary for the public to be accepting of nanomedicine because of the predicted impact it will have on the betterment of healthcare.

2. METHODOLOGY AND HYPOTHESES

2.1. TARGET POPULATION

In order to gather an accurate description of the public's opinion about nanomedicine, the target population needs to be closely defined. In an attempt to maintain a high response rate, the determined target public was the Worcester Polytechnic Institute (WPI) student body. Nine classes were strategically picked to maintain both a good representation of the WPI student body as well as a proper random sample, maintaining an accurate male to female ratio and class-year distribution[27]. WPI's current male and female percentages are 76% and 24% respectively[28]. Also, WPI currently has a class-year distribution of 23% seniors, 25% juniors, 26% sophomores, and 26% freshmen. As suggested from Salant and Dillmans' book *How to Conduct a Survey,* a 95 percent confidence interval with a five percent sampling error is desired for reputable survey results[29]. Therefore, for the target population of 2,851 students, the recommended sample size would be approximately 250 students[30].

2.2. MODE OF DATA GATHERING

Once the desired sample size was determined, the mode of information production needed to be determined. Among the various methods of surveying: e-mail, telephone, mail, drop-off, and interview, the "drop-off method" was best-suited for the constraints of the project (i.e. money, time, population size, etc…). Students of nine classes were handed a survey constructed by the IQP team which could be completed in under ten minutes.

2.3. DESCRIPTION OF SURVEY

The survey[31] was purposely designed to explore the goals of the IQP project. Throughout its creation, the document was carefully evaluated for proper surveying techniques. Under the guidance of Dr. Doyle, a professor of Psychology at WPI with

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[27] See APPENDIX B for table of courses surveyed.
[28] www.wpi.edu
[29] Salant,P. and Dillman,D. How to Conduct Your Own Survey. New York: John Wiley & Sons, Inc, 1994.
[30] See APPENDIX C for table of 95% confidence interval.
[31] See APPENDIX A for survey.

surveying expertise, and the text, *How to Conduct your Own Survey*[32], the IQP team formed a four-paged document, with each question being strategically shaped to further investigate a parameter or goal of the survey. Common surveying techniques were integrated. For instance, the questions were formulated in a manner that would not present any bias. Statements were not worded in a "closed-ended" form, to minimize the accuracy of the survey: instead of forcing the respondents to compartmentalize themselves by circling "yes" or "no" to a response, the questions were formulated to allow the respondents to answer: "agree", "disagree" or "not sure." A specific example is seen in Question 16 of Appendix A.

The first section of the survey utilized three questions to explore the Cognitive Miser vs. Scientific Literate Models, one of the three primary objectives of the survey. The questions explored the tendency of the individual to rely on the media to reach a conclusion and the other basic decision-making characteristics that were defined in "The public and nanotechnology: How citizens make sense of emerging technologies"[33]. The manner that the respondents answered the three questions determined their decision-making type: cognitive miser or scientific literate.

Question 4 of the survey was shaped to define the six most influential factors employed when deciding to use a new medicine. Fifteen various factors, including a space to list others, were mentioned—ranging from financial reasons, to information on the package to family history—and the respondents were asked to circle the five most valuable to them when deciding to use a new medicine.

Questions 5-15 were created as pairs to formulate a series of five questions to explicitly study the respondents' acceptance of nanomedicine—specifically the likeliness of using a medicine containing nanoparticles versus using a new medicine in general. Question 5 was paired with 11, question 6 with 12, question 7 with 13, question 8 with 14, and question 9 with 15. The respondents were asked to circle the degree of acceptance for each question with the aid of a scale ranging from values one to five. Within each of the five sets, the questions were framed very similarly; the only difference was one question

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[32] Salant,P. and Dillman,D. How to Conduct Your Own Survey. New York: John Wiley & Sons, Inc, 1994.
[33] Scheufele, Dietram A. and Lewenstein, Bruce V. "The public and nanotechnology: How citizens make sense of emerging technologies." Journal of Nanoparticle Research. Springer Inc. 2005.**7**: 659-661.

inquired about the likeliness of the respondents to use a new medicine under the conditions specified, while the other one included the likeliness of the respondent using a new medicine containing nanoparticles. Furthermore, each of the five sets was vigilantly constructed to explore one condition alone so as to obtain reliable results. The first set studied the likelihood of the respondents' using a medicine containing nanoparticles that would treat an illness with the same efficiency as the existing one. The second set explored the financial influence, specifically the effect on the person's acceptance of a nanomedicine if the cost was lower than an existing drug of the same efficiency. Set three investigated the likeness of using a nanomedicine if it were more efficient at treating an illness than an existing drug. The aspect of using a nanomedicine, in the form of a vaccine, while it was still in clinical trails was studied in question set 4. The final set inquired about the likeliness of using a nanomedicine based on the fact that a friend or family member has had success with.

The last parameter of the survey to be investigated, risk behavior, was on page four with a table listing several activities. Respondents were first asked to rate each activity, on a scale of 1-6, for the level of physical risk it posed. Secondly, respondents were asked to check all of the activities which they would participate in. This table aimed at evaluating the general risk behavior of the respondent as being safe, moderate, or risky. The risk-behavior personality was later used to explore a possible correlation between the respondent's acceptance of nanomedicine and his or her risk-behavior personality.

For general informational purposes, a section in the center of the survey contained a place for the respondent to define his or her sex, major, and class year. These questions were necessary to gauge the representation of the sample population and ensure that it was an accurate gathering of the WPI student body.

Another minor section of the survey contained two questions targeting the degree of media usage when deciding to accept a new medicine, and a medicine containing nanoparticles. In Appendix A these are questions 10 and 16.

2.4. DESCRIPTION OF GRAPHICAL REPRESENTATION OF DATA

The results of the three parameters investigated by the survey were graphically represented in a model of three axes, (*x, y, z*), as seen in Figure 3. The *x-axis* holds the cognitive misers at one end and the scientific literates at the other. The *y-axis* represents the risk behavior of an individual, with the conservative individuals on one side and the risk enthusiasts on the opposite side. The *z-axis* denotes the individual's acceptance of nanomedicine, with the top presenting those who are accepting of nanomedicine to some positive percentage and the bottom representing those who negatively view nanomedicine. The respondents will receive a value for each axis and their response distribution will be plotted on the axes chain in Figure 3.

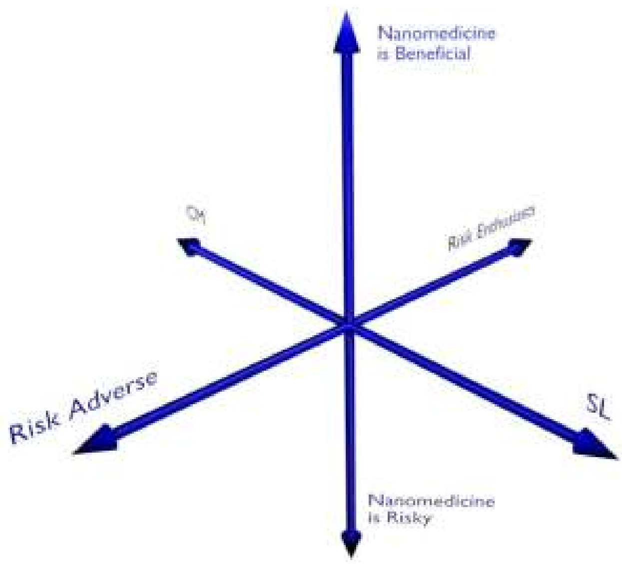


Figure 3: Graphical representations of the three parameters studied

2.5. EXPECTED DATA TRENDS

There are a series of expected trends in the data. One anticipated trend is that the results will show a greater percentage of Scientific Literates versus Cognitive Misers because the survey was taken only by WPI students. WPI is a technical school and thus is attended by students who are interested in scientific topics.

Another expected trend is that the Scientific Literate individuals might be more accepting of nanomedicine since they are in theory more interested in scientific topics and thus more prone to be accepting of a new emerging technology. In contrast, the Cognitive Miser individuals might be less accepting of nanomedicine because they are in theory individuals who make decisions with less information. This can result in producing a greater fear towards accepting an emerging technology such as nanomedicine because its benefits and risks might not be understood sufficiently.

A trend may be present between the acceptance level of nanotechnology and the risk behavior of each individual. In general, a risk-driven individual is more prone to be accepting and being enthusiastic about the unknown. This attribute could evolve into accepting emerging technology, such as nanomedicine. In contrast, a risk-adverse individual might be less prone to partake in activities that are unfamiliar. Thus, these individuals would be more hesitant to participate in a new technology such as nanomedicine.

Overall, if the results obtained from the survey allow us to determine the most influential factors as well as any trends among the two aspects of the decision-making process in accepting nanomedicine, valuable conclusions might be made about how to achieve a higher social acceptance of nanomedicine.

3. RESULTS AND ANALYSIS

3.1. DESCRIPTIVE RESULTS

The descriptive results from the survey met a 95% confidence interval with a +/- 5% sampling error as the sample population size was approximately 250 WPI students[34]. The sample population proved to be a good representation of the WPI population of 2851 students. The results obtained gave a male and female percentage of 77% and 23% respectively, compared to WPI's current male and female percentages of 76% and 24% respectively[35]. The results showed that the class distribution of the sample population was comprised of 13% seniors, 23% juniors, 23% sophomores, 40% freshmen, and 1% high school students taking a course at WPI. Currently WPI has 23% seniors, 25% juniors, 26% sophomores, and 26% freshmen.

One of the goals of this research was to determine the correlation of the two parameters on the acceptance of nanomedicine. The descriptive results for the two parameters studied are as follows. The acquired percentages of cognitive misers vs. scientific literates were 41% and 59%, respectively. Since WPI is an engineering school, a higher percentage of scientific literates was expected. The results for the second parameter studied, the population's risk behavior, consisted of 69% moderate, 23% safe, and 8% risky.

3.2. ANALYSIS

The average response for each question was also analyzed as part of our initial results. Figure 4 shows the averages of related questions plotted next to each other. It can be seen from the height of the bars that there is no real significant change from one question to the other of the same pair. This is an indication of the fact that our sample population is tolerant of nanomedicine: the fact that nanoparticles are introduced in one of the questions of the pair, does not change the answer of the respondent. As seen in Figure 4, the pairs Q6, Q12, and Q7, Q13 have a higher average than the others. These high averages in response are not surprising, since the first pair analyzes the factor of

[34] See APPENDIX C for table of 95% confidence interval
[35] www.wpi.edu

lower cost medicines and the other pair investigates the use of medicine of higher efficiency.

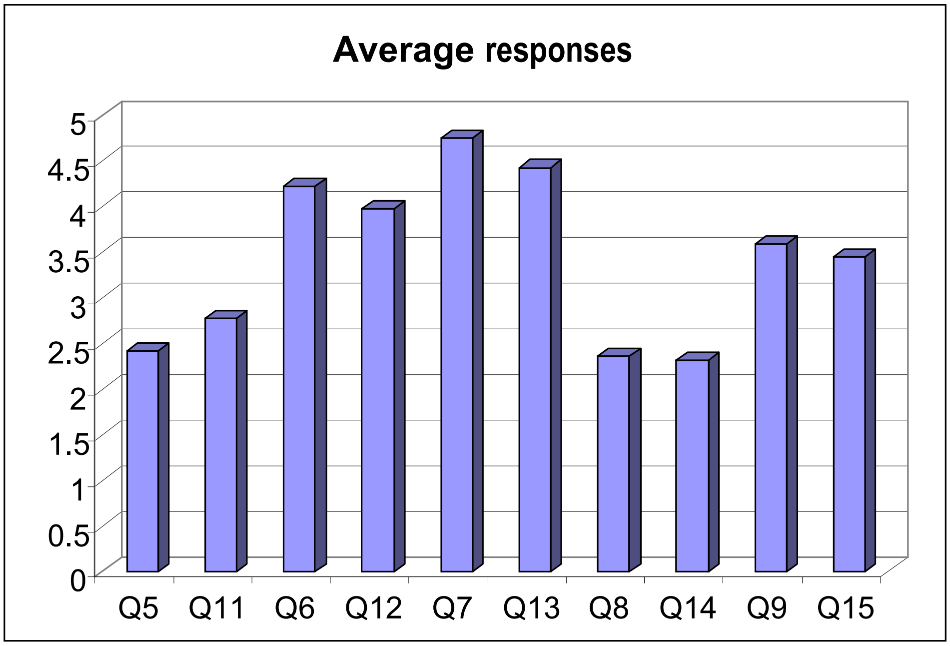


Figure 4: Averages of responses for the five sets of questions

In accomplishing the primary goal of the survey, the acceptance of nanomedicine was measured through five sets of questions. The values obtained for the change in acceptance of the five sets of questions were a key component of the analysis of the survey as they were correlated to the two parameters studied. Question 5 was paired with question 11, question 6 with question 12, 7 with 13, 8 with 14, and 9 with 15. For these five sets of questions, the respondents were asked to circle a number indicative of their degree of acceptance.

An average change in acceptance of zero symbolized that including nanoparticles in a medicine had no effect on the individual's decision when compared to today's medicine. In other words, the individual tolerated the nanomedicine, showing no change in response when the situation described in each question contained nanoparticles. For a change in acceptance value greater than zero, the population preferred the inclusion of nanoparticles in today's medicine; thus, the nanomedicine part of the set of the question was more accepted. An average acceptance value less than zero denoted a resistance of the respondent to a medicine containing nanoparticles.

3.3. CM VS SL AND ACCEPTANCE LEVEL OF NANOMEDICINE

One aspect of the analysis that was investigated was the correlation between acceptance of nanoparticles in medicine and the decision-making type of the individual. The predicted trend was that respondents who were found to be scientific literates would have a higher tolerance for the inclusion of nanoparticles in medicine than cognitive misers. Two graphical representations exist of both cognitive misers and scientific literates: the averaged values of each of the five question sets and the difference value for the change in acceptance for each responder. The respondent was first placed in either the cognitive miser group or scientific literate group before being graphed. The average value for each set of the five corresponding questions, ranging from question five to question fifteen, for the groups of cognitive misers and scientific literates is seen on Figure 6. As shown in Figure 5, graphs of the responses of cognitive misers and scientific literates for each of the five corresponding sets of questions were created. As with all the graphs in this section, the values graphed from the blue line represent all the cognitive misers' change in acceptance values; the pink data points represent the change in acceptance values of scientific literate individuals.

Unlike Figure 7, which shows a spectrum of the responses for question 11 and 5, Figure 6, shows the average change in acceptance value for both cognitive misers and scientific literates with respect to each of the five sets of questions. As predicted, the average change in acceptance for scientific literates was higher—the value is more positive—for each set of questions. However, the magnitude is so small, that no results can be obtained to support the IQP team's prediction. Figure 5 show the same graphical display of data points, thus supporting the fact that the change in acceptance is so small among the questions. This symbolizes that overall, regardless of the scenario, the sample population is tolerant of nanomedicine.

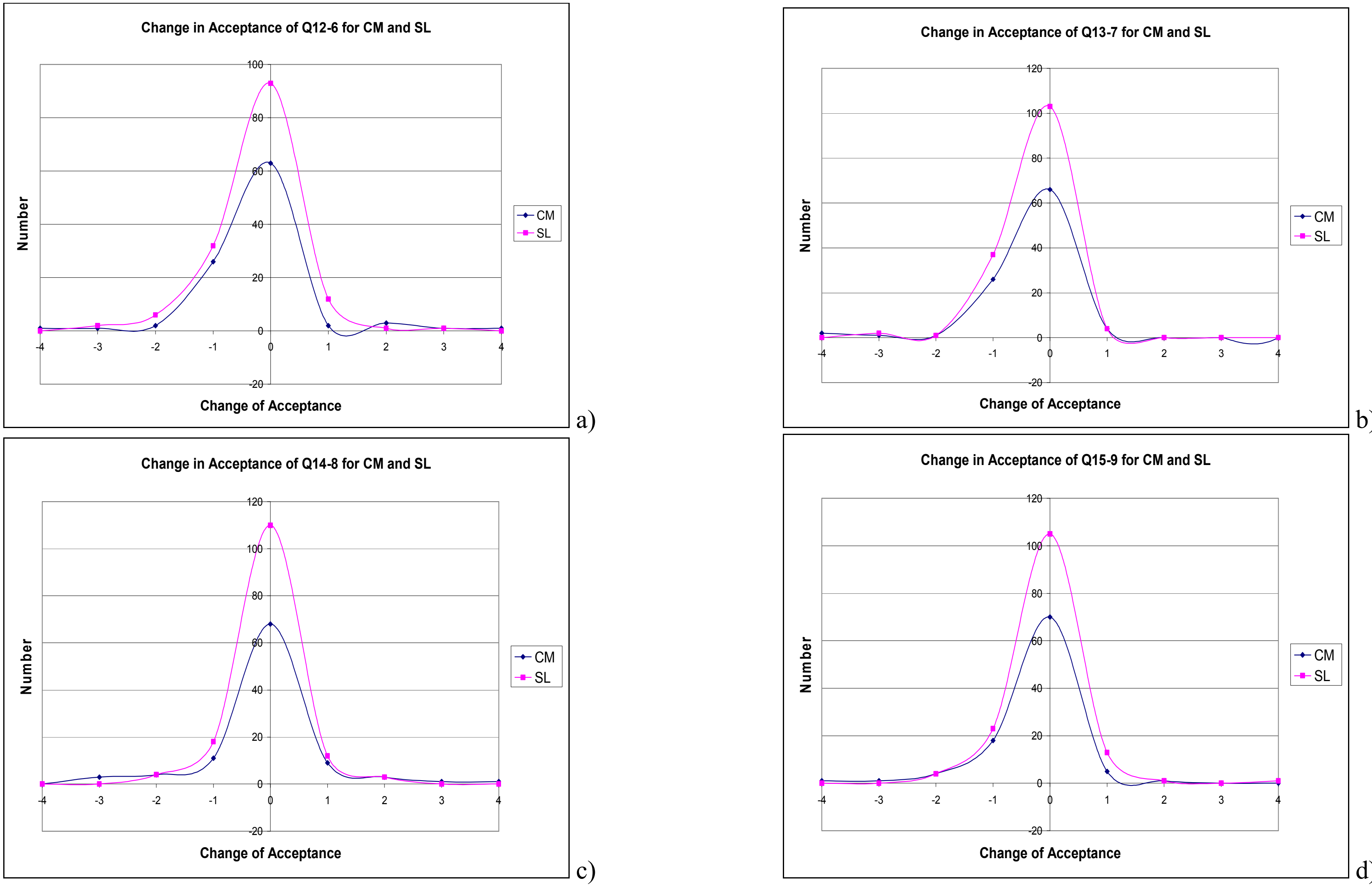


Figure 5: Change in acceptance for four of the five sets of questions for CM and SL.

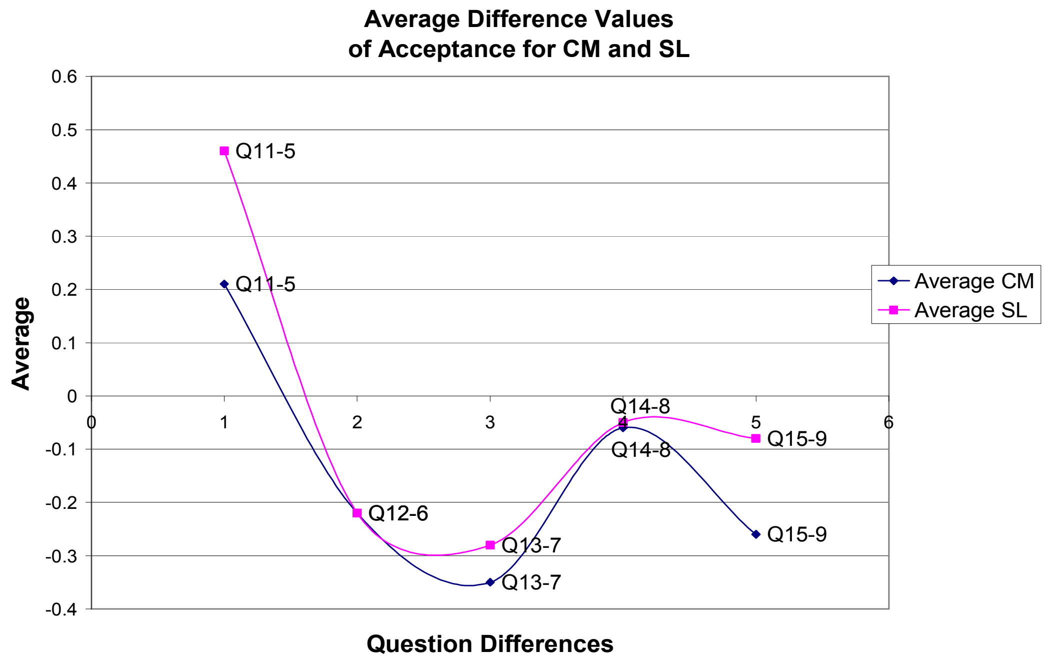


Figure 6: Average distribution of acceptance for CM and SL

The only question that yielded a "positive result" was the first question set, Q11-Q5; this symbolized a slight social acceptance of the sample population's wiliness to use nanomedicine. Therefore, the respondents ranked themselves higher; they were more likely to use "A new medicine containing nanoparticles to treat an illness with the *same* efficiency as an existing medicine (all other characteristics being equal)" when compared to the value they selected for likeliness of using a new medicine that was fabricated with current production method[36]. However, the magnitude of showing overall acceptance of this question is so small, less than 0.5 for both decision-making types, showing that there is no significant change between the pairs of questions.

[36] See APPENDIX A for survey.

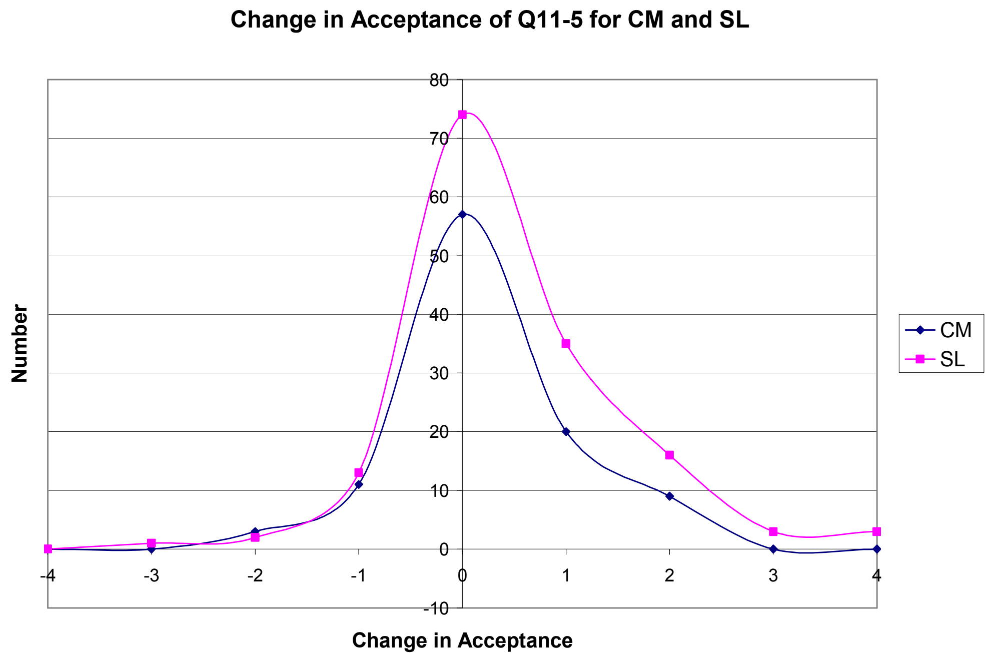


Figure 7: Q11-5 change in acceptance for CM and SL

Unexpected results were showed in the third set of questions; it explored the public's acceptance of using a drug containing nanoparticles that was more efficient than the existing drugs on the market. Surprisingly, both decision-making types felt the least accepting of purchasing medicine containing nanoparticles under the restraints of the question set. The cognitive misers were less likely to use the nanoparticle containing drug with an average value of acceptance of -.35, while the average scientific literate value was -0.28[37]. Figure 5 shows the distribution of responses for all respondents respective to their cognitive miser or scientific literate classification.

3.4. RISK BEHAVIOR AND ACCEPTACE OF NANOMEDICINE

A careful analysis of the acceptance of nanomedicine as a function of risk behavior reveals a very similar distribution with the acceptance of nanomedicine as a function of cognitive and scientific behavior. Furthermore, the three different categories of risk behavior have almost identical distributions among themselves as well.

[37] See figure 5b for graphical representation.

In total we have analyzed 65 safe, 158 moderate, and 27 risky respondents. As with the cognitive and scientific types, we examined the change in acceptance for each question related to nanomedicine and the overall acceptance level for each question pertaining to different factors. For all the questions, it is clear that the distribution in answers is the same no matter what the risk behavior is. This is an indication of the fact that these different types react in the same way to the factors that each question explores. More importantly, this similarity extends for all the five pairs of questions analyzed.

Questions 11 and 5 both measure the impact of a new medicine that has the same efficiency. It is clear from the graph that all three types manifest a similar change in

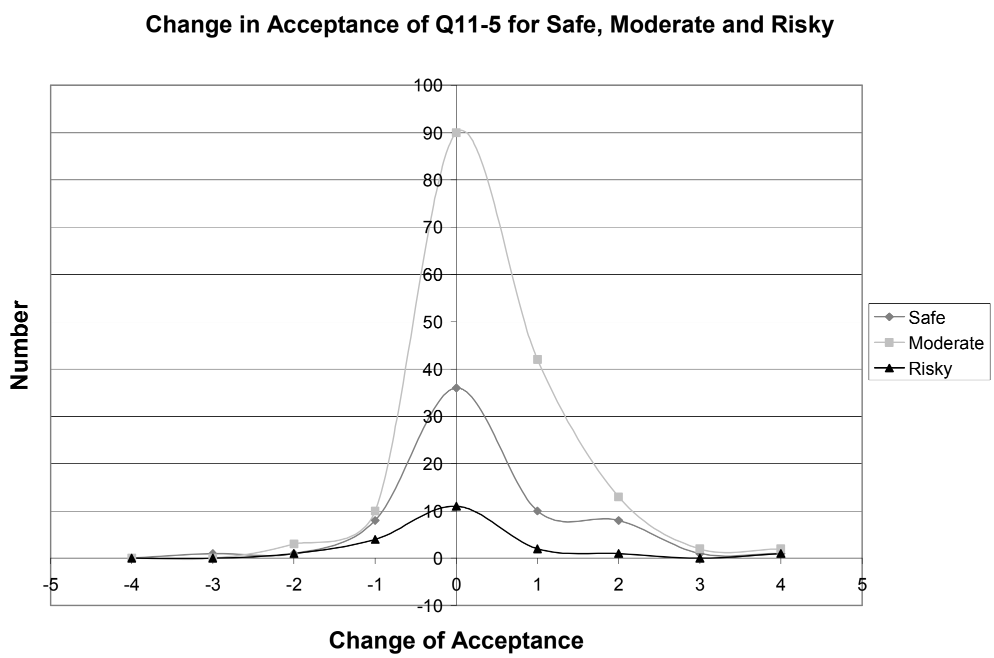


Figure 8: Q11-5 change in acceptance for safe, moderate, and risky

acceptance. The other questions measure the factors of price, efficiency of the medicine, clinical trial of vaccines, and friends or family advice. For all these factors, the graph above is a good representative of the similarity trend within the same question. In Figure 9 the following four graphs show the similarity trend not only within the same question, but for different questions as well. This trend seems to be universal for both the cognitive and risk types.

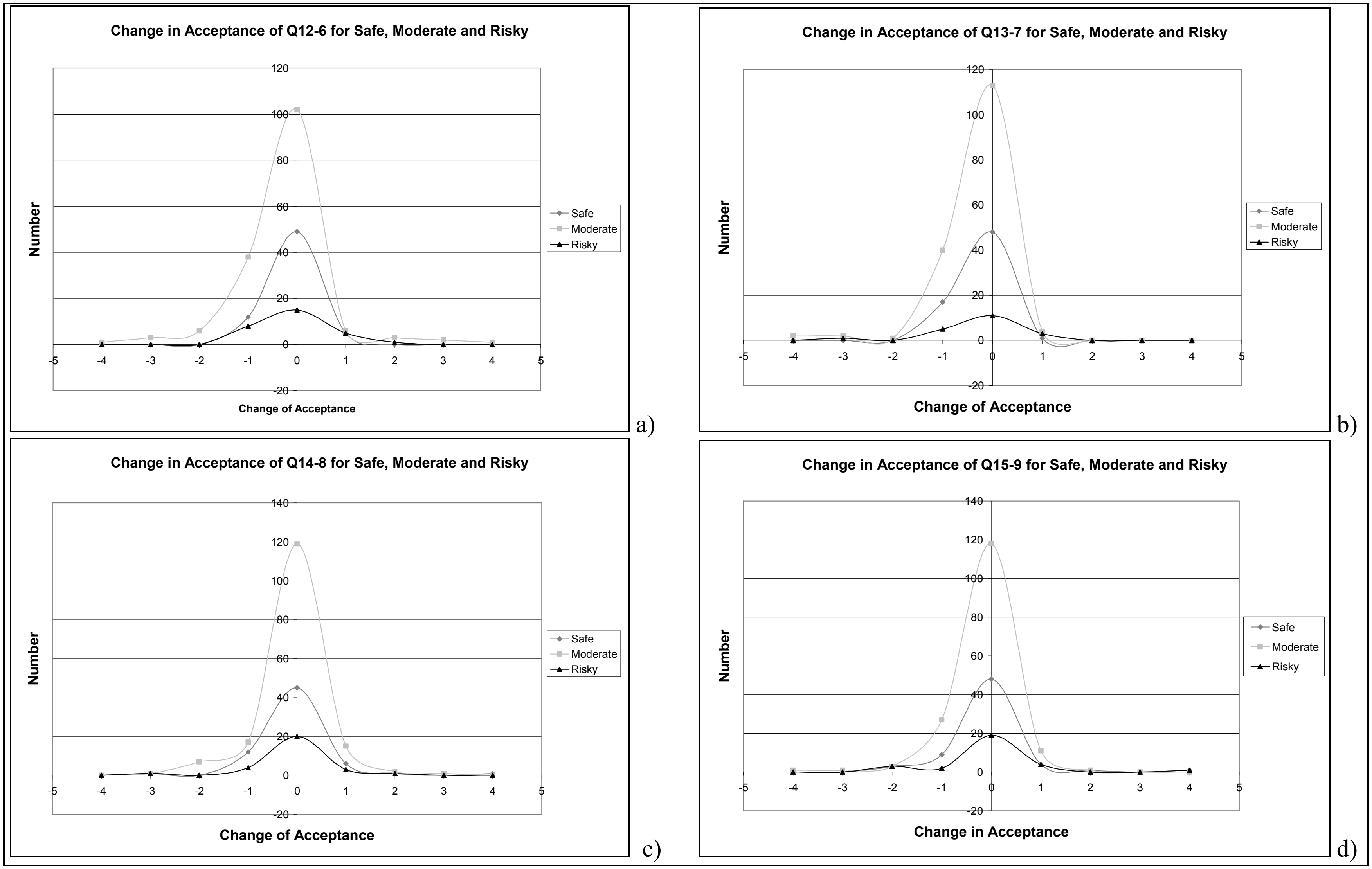


Figure 9: Change in acceptance for four of the five sets of questions for risk behavior.

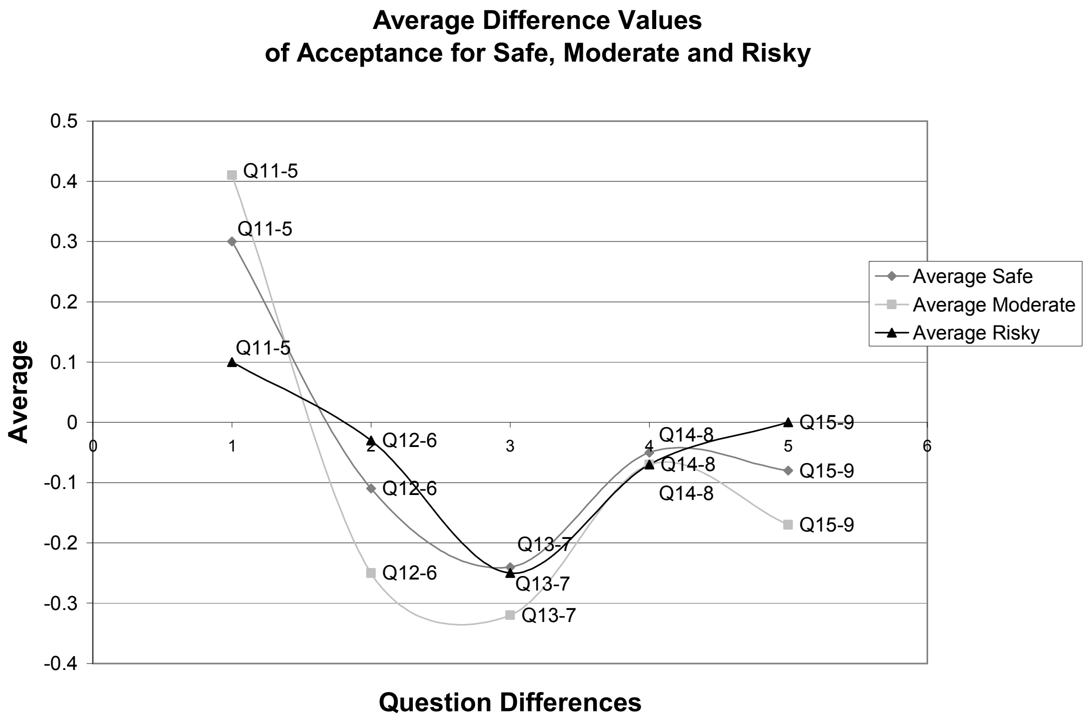


Figure 10: Average acceptance distribution for risk behavior

The overall acceptance behavior, measured by the average, also shows a similar trend for the three different types. Figure 10 shows that the respondents were accepting when the medicine contained nanoparticles and all other factors were left unchanged. As soon as another factor was introduced, the respondents became non-accepting, regardless of their risk type. It is to be noted that the average values were relatively small, but, nevertheless, they represent the measure of the acceptance level. The moderately risky respondents were the most accepting in the case when the only change was the fact that the medicine is new in the market. The safe respondents were more accepting, and surprisingly, the least accepting of using a nanoparticle-containing drug were those having risky behavior. When the new medicine was cheaper and containing nanoparticles, the moderate respondents went to the other extreme, being the ones that were the most denying, followed by the safe and the risky; for Q12-6 respondents having risky behavior were the most accepting. The third question pair, Q13-7, focused on a new more efficient medicine containing nanoparticles. Under this scenario the safe respondents became the most accepting while the risky respondents became the least accepting. In the case of vaccines, Q14-8, the moderate and risky respondents manifested the same degree of acceptance, while the safe respondents were the most accepting. Risky respondents were the least accepting when they were asked to rate the likeliness of using a medicine with nanoparticles that a family member or friend suggests. Safe respondents were most accepting.

When the averages in acceptance vs. the risk and cognitive types were compared,

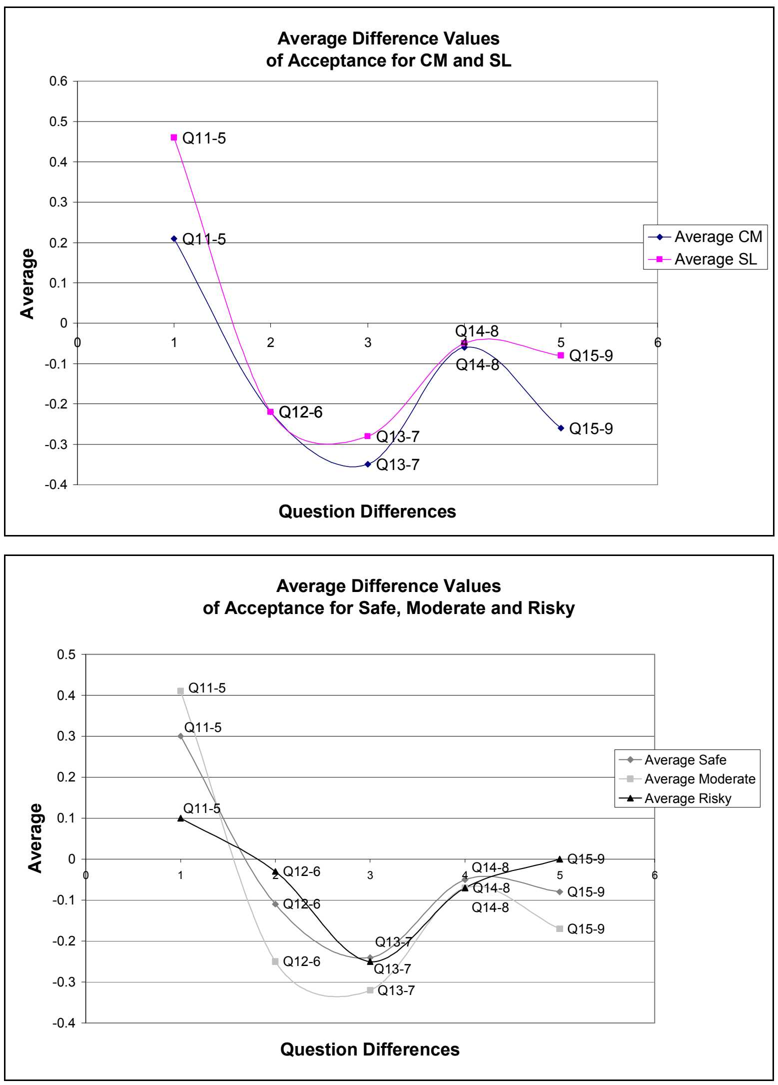
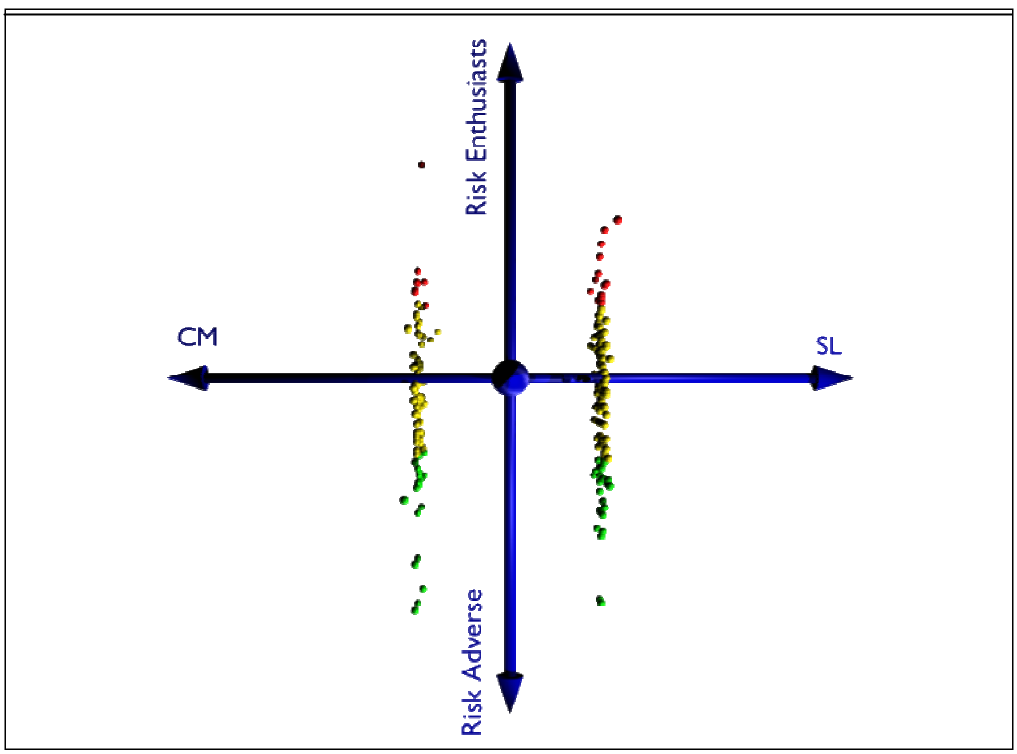


Figure 11: Comparison of average distribution in for risk behavior and CM/SL

very similar patterns are apparent, as seen in Figure 11. These similarities could be an indication of the fact that acceptance of nanomedicine is universal and does not depend on the risk behavior or the cognitive type.

3.5. GRAPHICAL REPRESENTATION OF DATA

To have an overall view of our data, they were plotted in a 3D graph shown in Figure 133, where the x-axis represents the risk behavior, the y-axis the cognitive and scientific types, and the z-axis the social acceptance of nanomedicine. To plot the cognitive and scientific types a value of -1 was assigned if the responder was a cognitive miser and a +1 value if the responder was a scientific literate. The overall acceptance of a responder was measured by the average of all the differences calculated from the pairs of questions from 9 to 15. A color code was assigned to the risk behavior types: green symbolizing a risk adverse, yellow a moderate, and red signifying a risk enthusiast. The following graphs plot the points for all 250 respondents. A 2D projection of our data is first given so that the points can be viewed easily. The top graph of Figure 12 shows a perspective view of the points. A careful look at the graphs affirms the results obtained from the individual graphs above: there is no correlation between cognitive, scientific and risk types with the social acceptance of nanomedicine. Furthermore, looking at the acceptance axis (z-axis)



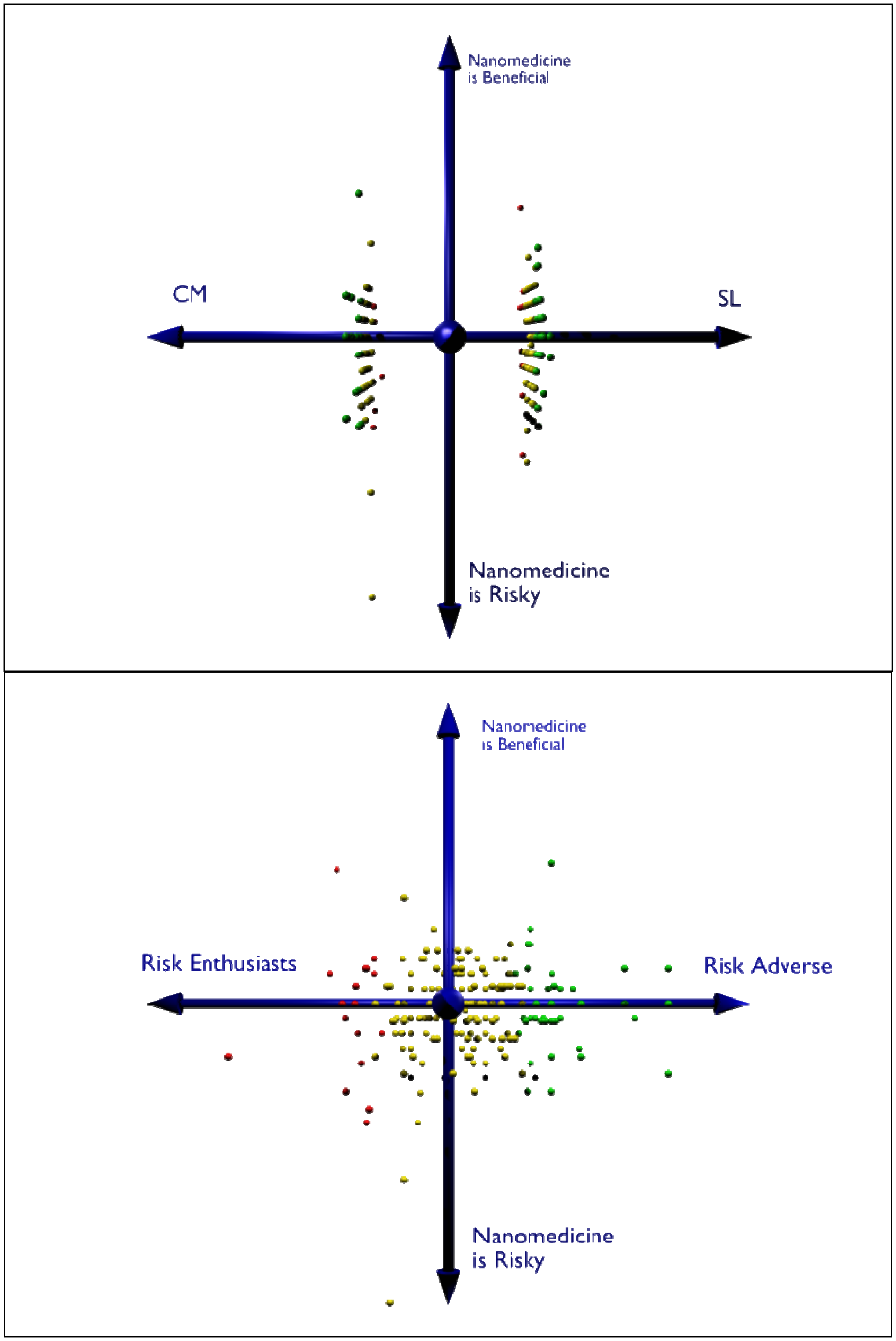


Figure 12: 2D projections of data from three angles

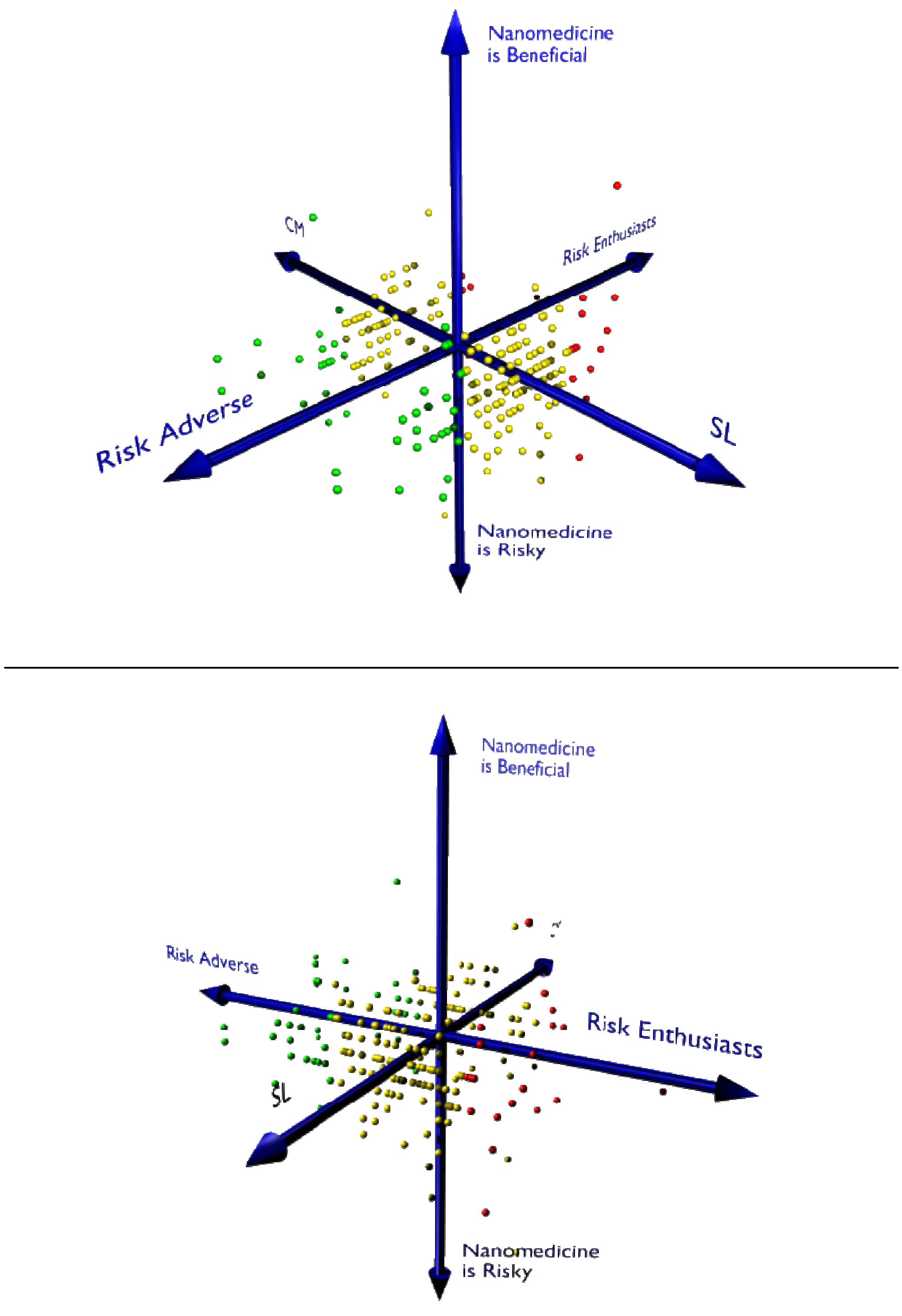


Figure 13: Two views of complete data

it is clear that the data lie very close to the origin, indicating that the sample population is more tolerant of nanomedicine. However, for the sake of correctness, the overall average of the entire data points is -0.21, a value very close to zero but nonetheless a negative value.

3.6. MOST INFLUENTIAL FACTORS IN ACCEPTING A NEW MEDICINE

Among the fifteen factors available, six top factors were determined: doctor's advice, clinical research, side effects, FDA approval of the medicine, information on package, and research journals, respectively. Figure 14 illustrates the percentages of each of these factors that were chosen by the respondents. After the fourth top factor, information on package, there was a drop of approximately 50 responses, and after the sixth top factor, research journal, a drop of approximately 50 responses occurred. The remaining nine factors decreased constantly in the number of times they were chosen. This result proves to be insightful, as the ultimate goal was to find the most influential factors for social acceptance of nanomedicine.

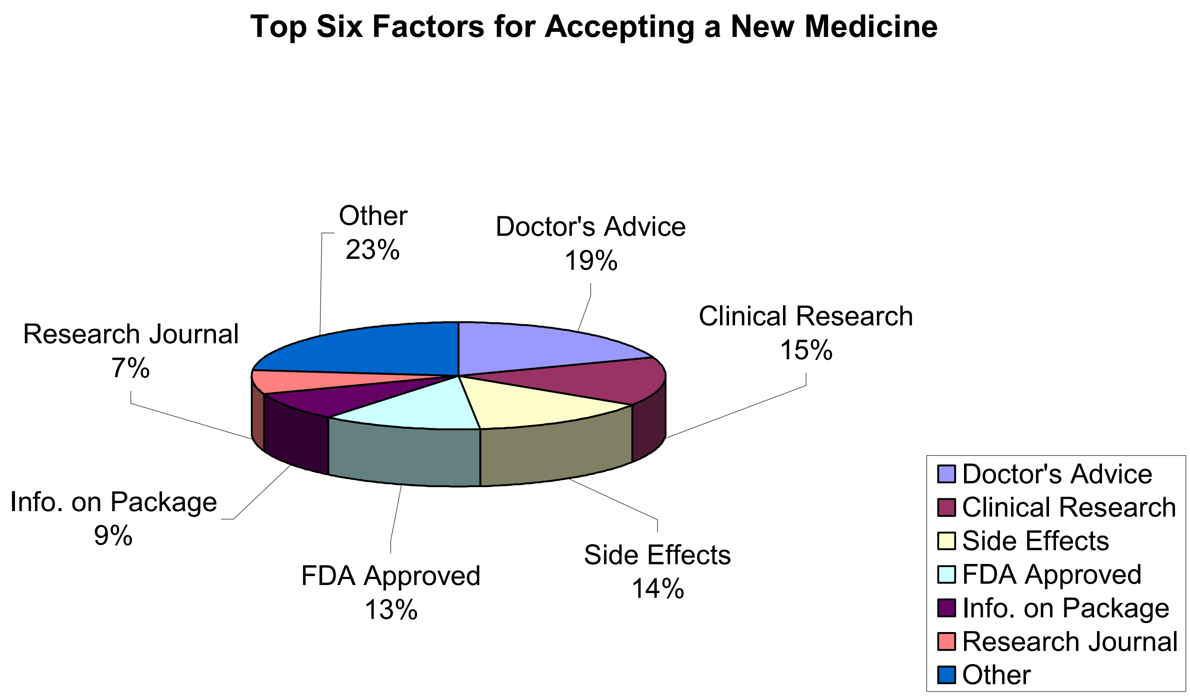


Figure 14: Top six factors for accepting a new medicine

4. CONCLUSIONS

4.1. IMPLICATIONS FOR THE FIELD OF NANOTECHNOLOGY

The survey allowed for insight into the decision-making process in acceptance of nanomedicine. It was found that there is no correlation between the social acceptance of nanomedicine and the cognitive miser and scientific literate models as well as with the risk behavior of the respondents. The data distribution for the cognitive misers and the scientific literates in correlation to the acceptance level of nanomedicine resulted in the same bell curve with the maximum lying on the zero value for the x-axis. This is representative of how the inclusion of nanoparticles in medicine has no increase or decrease on the likelihood of our target population using that medicine. This same bell curve existed for the three risk behaviors studied in the survey: risky, moderate, and safe individuals. The results obtained were not expected, as the theories of the cognitive miser and scientific literate models suggested there would be an increase of acceptance of nanomedicine for scientific literates and a decrease for cognitive misers. In a similar way, it was expected that risky individuals would have an increase in their acceptance of nanomedicine, moderates would show no change of acceptance, and safe individuals would show a decrease in their acceptance of medicine containing nanoparticles.

Even though the results show that there is no significant difference on how the individual reacts toward the inclusion of nanoparticles in medicine, the fact that the average change of acceptance of the 250 individuals surveyed was -0.21 has to be discussed. This value has two interpretations: the first being that it is a negative value; therefore, it represents the fact that the overall population surveyed was not tolerant of nanomedicine. The other being that it is a value very close to zero, which means that the population is neither tolerant nor accepting of nanomedicine. In conclusion, since the possible differences could range from -4 to 4, a value as close to zero as -0.21 was considered to represent that the target population showed no change in acceptance between the use of a new medicine containing nanoparticles and a new medicine without nanoparticles. It was concluded that a possible cause for such a result could be the fact that the survey was conducted in a technical college, where the majority of its students have a predisposition to be interested in science and its innovations, such as nanotechnology and its applications.

Finally, one very insightful conclusion from the survey was that the most influential factors used when determining to use a new medicine were: doctor's advice, clinical research, side effects, FDA approval of the medicine, information on package, and research journals. It is evident that the significance of knowing which factors the public has articulated as the most influential in their decision-making process for the use of a new medicine, serves as being very helpful for marketing strategies. The fact that our target population also presented a neutral reaction towards the inclusion of nanoparticles in medicine is complementary to the factors that were determined important when deciding to use a new medicine, as they can also be applied to public-relations strategies for nanomedicine.

In today's world, nanotechnology is no longer an innovation of the future; it is of great importance to public health that nanotechnology be socially accepted by the general population. Thus, determining the factors and parameters that are most influential in the acceptance of nanomedicine is of crucial importance to not only manufacturers, investors, and researchers, but also the general public.

4.2. RECOMMENDATIONS FOR FUTURE RESEARCH

For future IQP teams, it is recommended that the direct role of the media on the public be explored thoroughly, as the two questions, questions 10 and 16 which directly targeted this relationship, were found inconclusive. The vast majority of the respondents' data to these questions denied any influence of advertising towards swaying their decision to use a new medicine. However, due to a known journalism tactic called "media framing," a case could be created to argue the importance of the media's role for achieving social acceptance of nanomedicine. Therefore, it is advised that the data from the 250 respondents be employed to propel this investigation.

Also, since the current IQP team had only three weeks to analyze all the data the survey provided, it is suggested that the next IQP team delve deeper into the respondents' answers and search for other possible findings that the data have to offer. Perhaps, other connections can be made, since no conclusive correlations between the Cognitive Miser and Scientific Literacy Models and an individual's risky behavior to the public's acceptance of nanomedicine could be reached.

The chief recommendation for next year's team is to distribute this survey to Clark University students and compare the results both between the sample populations' social acceptance. Since WPI is a technical school, it is suspected that social acceptance of nanomedicine would be higher than in a university attended by diverse individuals of various liberal arts and technical majors. If the results could be compared, perhaps a relationship among the parameters would be observable, and a more thorough understanding of the public's acceptance of nanomedicine would be possible, at least for college populations.

Besides IQP members, others can benefit and build on the results of the 2006-2007 IQP project. Technological manufacturers, scientists, and investors in nanomedicine can recognize the public's articulated influence by doctor's advice, clinical research, side effects, FDA approval, information on package, and research journal, in order of importance. Specifically, personnel in the field of media can capitalize on the knowledge of these important factors and design medical packaging and subsequent advertising to knowingly include these aspects. Uncovering the needs of the public for accepting the various areas of nanotechnology is beneficial to persons in various areas of work. Thus, it is imperative to continue the investigation of social factors influencing the decision-making process of emerging technologies.

5. ACKNOWLEDGMENTS

We would like to thank gratefully Professor Nancy Burnham for her great guidance and support, Professor James Doyle for his advice on designing a scientifically valid survey, all the professors who allowed time in their classes for us to distribute the surveys, Professor Jayson Wilbur for helping us in the analysis of the data, James Stickney for helping us create the 3D graphs as well as the 2D projections, and the librarians who guided us in our search of the available literature.

6. APPENDIXES

6.1. APPENDIX A: SURVEY

Please answer the following four questions so that we can learn about your decision-making process.

1. **When you bought your last computer which resource did you use to help you decide? (Please circle one option)**

A friend who has used it

Research journal

Family member

Product website

Other (please specify): _____________

2. Rank the following resources you use when gathering information about a new technology? (Rank)

1=most important **6=least important**

- ☐ A research journal
- ☐ News
- ☐ T.V commercials
- ☐ A friend
- ☐ Educational/Scientific TV programs
- ☐ Library/Online database

3. How often did you read the "Science and technology" section of the newspaper (hard copy or online) over the past 2 months? (Please circle)

1 Never

2 Less than half the time

3 Half the time

4 More than half the time

5 Always

4. Of the following factors which would you consider the <u>five</u> most important when deciding to use a new medicine? (Please Circle)

- Relative's advice
- Research Journals
- Side effects
- Friend's advice
- Advertisement
- Clinical results
- Information on the package
- Doctors' advise
- Company producing the medicine
- Equivalent medicines
- Financial
- Magazines
- Religious
- FDA approved
- Family history
- Other(s):_________

Please provide this basic information about yourself

A. Male Female (Please circle)

B. Major(s): _______________

C. Class Year: ________

Please answer questions 5-10 which pertain to the factors that are important to you when using or buying a new medicine.

5. If there were a new medicine to treat an illness with the <u>*same* efficiency</u> as an existing medicine (all other characteristics being equal), how likely would you be to use the new medicine? (Please circle)

Not at all 1 2 3 4 5 Very likely

6. If there were a new medicine that treats an illness and it were <u>cheaper</u> than an existing medicine (all other characteristics being equal), how likely would you be to buy the new medicine? (Please circle)

Not at all 1 2 3 4 5 Very likely

7. **If there were a new medicine that treats an illness *more* efficiently than the existing medicine (all other characteristics being equal), how likely would you be to use the new medicine? (Please circle)**

Not at all 1 2 3 4 5 Very likely

8. **How likely would you be to use a vaccine to acquire immunity against a life threatening disease while it is still in clinical trials? (Please circle)**

Not at all 1 2 3 4 5 Very likely

9. **How likely would you be to use a new medicine that a close friend or family member has had success with and suggests to you? (Please circle)**

Not at all 1 2 3 4 5 Very likely

10. **How often do you rely on advertisements when deciding to use a new medicine? (Please circle)**

Never 1 2 3 4 5 Every time

Please answer questions 11-16 which pertain to the application of nanotechnology in the field of medicine. The following definitions are given to help you answer the following questions with a basic knowledge about nanotechnology and nanomedicine.

Nanotechnology is a branch of technology that is concerned with devices that have nanometer size. A nanometer is 1 billionth of a meter. Take one centimeter and divide it in ten million equal parts and pick one of those parts: that is one nanometer. Nanoparticles are any nanometer size particles that are used in nanotechnology to perform a desired function. The application of nanotechnology in the field of medicine uses such nanoparticles, and is termed nanomedicine.

11. If there were a new medicine containing nanoparticles to treat an illness with the *same* efficiency as an existing medicine (all other characteristics being equal), how likely would you be to use the new medicine? (Please circle)

Not at all 1 2 3 4 5 Very likely

12. If there were a new medicine containing nanoparticles that treats an illness and it were cheaper than an existing medicine (all other characteristics being equal), how likely would you be to buy the new medicine? (Please circle)

Not at all 1 2 3 4 5 Very likely

13. If there were a new medicine containing nanoparticles that treats an illness *more* efficiently than the existing medicine (all other characteristics being equal), how likely would you be to use the new medicine? (Please circle)

Not at all 1 2 3 4 5 Very likely

14. How likely would you be to use a vaccine containing nanoparticles that would provide immunity against a life threatening disease while it is still in clinical trials? (Please circle)

Not at all 1 2 3 4 5 Very likely

15. How likely would you be to use a new medicine containing nanoparticles that a close friend or family member has had success with and suggests to you? (Please circle)

Not at all 1 2 3 4 5 Very likely

16. Do you agree or disagree with the following statement: "I would rely on advertisements when deciding to use a new medicine <u>containing nanoparticles</u>". (Please circle)

Agree Disagree Not Sure

Circle the appropriate number to the right of each of the following activities to indicate their ***level of physical risk****. In the column to the far right please* ***check off*** *the activities that you would participate in. Please refer to the "Physical Risk Scale" below.*[38]

Physical Risk Scale

No Physical Risk 1 2 3 4 5 6 → Extreme Physical Risk

	Activity	Physical Risk Scale						Check if you would participate
1	Water skiing	1	2	3	4	5	6	
2	Eating fatty foods	1	2	3	4	5	6	
3	Parachute jumping	1	2	3	4	5	6	
4	Going on a picnic	1	2	3	4	5	6	
5	Scuba diving	1	2	3	4	5	6	
6	Driving recklessly	1	2	3	4	5	6	
7	Rock climbing	1	2	3	4	5	6	
8	Bungee	1	2	3	4	5	6	

[38] Physical risk scale was adopted from a previous scale designed by Dr. David J. Llewellyn which can be found in http://www.risktaking.co.uk/resources.htm.

	Jumping		
9	Using hallucinogenic drugs	1 2 3 4 5 6	
10	White water kayaking	1 2 3 4 5 6	
11	Smoking cigarettes	1 2 3 4 5 6	
12	Having unprotected sex	1 2 3 4 5 6	
13	Not exercising regularly	1 2 3 4 5 6	
14	Drinking until you pass out	1 2 3 4 5 6	
15	Horseback riding	1 2 3 4 5 6	

Please remember to check off the activities that you would participate in.

6.2. *APPENDIX B: TABLE OF COURSES SURVEYED*

Date	Time and Location	Professor	Course	Number of Students	Partners Attending	Number of Surveys Completed	Surveys Excluded[39]	Surveys
Tues.11/28	9:20 am OH 223	Burnham	Inter. Mechanics II	38	Nathalia Ergys	33	1	32
Thurs.11/30	11:00 am OH 107	Arguello	Biochem. II	68	Nathalia Ergys	33	4	29
Fri. 12/1	10:00 am SL 123	Manzari	Inter. Span. II	25	Kate	16	1	15
Mon. 12/4	11:00 am OH 223	Mott	Intro. to Literature	25	Ergys	10	0	10
Mon. 12/4	1:00 pm HL 218	Doyle	Social Psychology	56	Kate Ergys	37	1	36
Tues. 12/5	9:00 am DH	Heinricher	Calculus II	13	Nathalia Kate	13	0	13
Tues. 12/5	4:00 pm WB 229	Oliveira	Calculus IV	35	Kate Nathalia Ergys	45	4	41
Thurs. 1/25	1:00 pm FL 311	Riviera	Spanish	40	Kate	35	4	31
Mon. 1/22	3:00 pm FL 320	Ciaraldi	Webware CS	54	Nathalia	45	2	43
Total						267	17	250

[39] Data from excluded surveys were incomplete or unusable from one or more of the primary aspects studied.

6.3. APPENDIX C: TABLE OF 95% CONFIDENCE INTERVAL

Population Size	**+/- 3% sampling error**		**+/- 5% sampling error**		**+/- 10% sampling error**	
-	50/50 Split	80/20 Split	50/50 Split	80/20 Split	50/50 Split	80/20 Split
750	441	358	254	185	85	57
1000	516	405	278	198	88	58
2,500	748	537	333	224	93	60
5,000	880	601	357	234	94	61

6.4. APPENDIX D: IN-DEPTH DESCRIPTION OF SURVEY ANALYSIS

Cognitive Miser vs. Scientific Literate Evaluation

The determination of the decision-making type (cognitive miser or scientific literate) was decided with the aid of the first two questions of the survey. Question one, as seen below, consists of options one and three as being cognitive miser responses. If the respondent circled option two or four they would be deemed as a scientific literate for this question.

1. When you bought your last computer which resource did you use to help you decide? (Please circle one option)

A friend who has used it

Research journal

Family member

Product website

Other (please specify): ________________

For any "other" responses the article, "The public and nanotechnology: How citizens make sense of emerging technologies" would be referenced.

Next the IQP team recorded the response of question two, as seen below.

2. Rank the following resources you use when gathering information about a new technology? (Rank)

1=most important **6=least important**

☐ A research journal

☐ News

☐ T.V commercials

☐ A friend

☐ Educational/Scientific TV programs

☐ Library/Online database

The top answer, the resource which was ranked number one, determined the decision-making type of question two. Next the decision-making types for both questions were compared. If the person received two of the same decision types—either both questions resulted in cognitive miser or scientific literate—the individual was considered automatically considered that type. However, if question one and two yielded different decision-making types, further investigation was needed. The IQP team then referred to the top three resources of question two and used that averaged type as the individual's recorded decision type.

Although three questions existed to determine the decision-making type of the respondents, the third question was exempted from the evaluation process. The majority of the individuals responded by circling the same choice; therefore, no conclusive evidence could be extrapolated from the question.

Risk Behavior Evaluation

The risk behavior of each individual was decided from the responses in the last question of the survey, located on page three. The respondents' were asked to circle the degree of physical risk each activity contained, on a scale from one to six, and check all the activities that they would partake in. For each respondent, the IQP team took the activities that the respondent "checked off" and found the average risk behavior of the activities. This value was then compared to a determined scale where 1- 2.67 symbolized the person as being safe, an averaged value of 2.68- 4.34 was moderate, and 4.35-6.01 denoted the individual as being risky.

Key of Risk Behavior		
S	**M**	**R**
1 - 2.67	**2.68 - 4.34**	**4.35 - 6.01**

The key was determined by taking the differences of possible averages—they ranged from one to six—and dividing by three. This difference was about 1.67; therefore, the interval for each risk behavior type needed to be 1.67 units of magnitude.