Rachel Sitts

Science Research

Section 1

From an early age, I was fascinated by math and science. Much of my childhood was spent blowing bubbles twice the size of my body at the Boston Science Museum and helping my uncle make paper maché volcanoes erupt with blue lava. I learned that science is not just a bunch of complicated formulas useful only to people in lab coats. Science can be applied to almost anything, which is why it is so exciting to me. It has opened my eyes to the world around me, and has helped me to understand concepts ranging from why salt should be added to water when cooking to the powerful force of a nuclear bomb.

At the end of my freshman year, I was given the option to take a three year course called Science Research. Initially, I was hesitant to take the class. I had always loved science and math, but the idea of creating and carrying out my own experiment seemed daunting to me. After much deliberation over the summer, I decided to sign up. Our summer assignment was to explore different topics in science and math by reading articles in science magazines, the newspaper, and science journals. At first, I was sure I wanted to study the brain. I have always been extraordinarily interested in the way the mind works. Whether it concerns the mind of an animal as complex as the human or dolphin, or as simple as the fly or bumblebee, I am fascinated by neuroscience.

However, I also became very intrigued by an article which introduced the enigma in creating a blue rose. I began to find more articles about botany, and became very interested in the way in which flowers use color to attract insects. Though to the human eye, some flowers appear simply yellow, to many insects, such as bumblebees and honeybees, these flowers are seen in ultraviolet. What may look like a plain yellow flower to me may look like a light purple flower with a deep purple bulls-eye pattern in the center to a bumblebee. My sophomore year in this class was filled with many journal articles about UV patterns and how they direct insects to the nutrients in the flower. I soon began to realize, however, that I was not particularly interested in carrying out an experiment with flowers, and I was presented with the challenge of changing my research topic. I began to reflect on what other articles I had read, and how these could help me choose a new area of study. I realized that what I wanted to research was often mentioned in my current flower journal articles: bumblebees.

Though I had a huge fear of bees, as many other people do, I was fascinated by the complex cognitive tasks these insects could perform despite their miniscule brains. I read numerous articles about how bumblebees were able to communicate with each other using various signals, such as by secreting pheromones to indicate when they have been successful when searching for food. It became clear to me that I wanted to study how bumblebees interact with each other and how their behavior affects their success during foraging.

Perhaps the most difficult part of science research is finding a scientist who is willing to take you on as a student in his or her lab. Scientists can be very busy people, and it is not usually easy to take time out of their schedules to instruct an inexperienced but eager young student. One of the best personal qualities to have when searching for a mentor is patience. It may take a while, but eventually it is possible to find someone to aid you in your research. It is very important, however, to make it clear that you take your work very seriously and that you are diligent about reading articles in the field of science you are planning on studying.

After e-mailing about five scientists, one scientist sent me a reply saying that he would be happy to have me in his bumblebee lab over the summer. I was very eager to perform an experiment in his lab; the only issue was that I live in the United States, and my mentor's lab is in London, England. Organizing my trip to the United Kingdom took a lot of time and effort, but eventually I had arranged to stay on the campus of the Queen Mary University of London for three weeks over the summer.

Once I had settled where I was going to perform my experiment, I had to make sure to stay on top of my research; I had to read many current journal articles about my topic and study the scientific method. Because I was taking Science Research, I decided to take an AP Statistics course. I knew that the information I learned in this class would be extraordinarily helpful when I started to analyze the results of my experiment. I made sure to become well-versed in different ways to organize data and the various tests that could be used to test for significance.

I arrived in London with a few ideas as to what experiment I could perform. After meeting with my mentor and looking at the equipment available to me at the lab, I started to get a good grasp of what my experiment would entail. I decided to do both a field and a lab experiment which would test how bees interact with each other while foraging. In the experiment process, it is (again) extremely important to be patient. Good science experiments take a lot of careful planning and often some trial and error. I spent my entire first week in London trying to figure out which type of flower would attract the highest number of bees for my experiment. After a week of only having about four visiting bees per day, I found a patch of lavender which was swarming with bees.

I found that the statistics I learned in my class in high school were extremely valuable to me after my experiment. Data can be very overwhelming at first. Before I analyzed my results, I had 171 pieces of data to consider. The statistics I learned helped me organize this data and choose a test to perform (Chi Squared Goodness of Fit Test). In most cases, math and science come hand in hand; it is impossible to separate the two. With the statistics I learned, I was able to figure out whether or not my hypothesis was proven and which trends in my data were significant.

My experiment definitely opened my eyes to the world of science and mathematics. Before I worked in the lab and the field, science seemed like a bunch of concepts written and explained in textbooks. Being able to see how these concepts applied to the real world made me more aware of my surroundings. I realized how important the field of science is in our society and how it can be used to benefit humans as well as animals. Although an experiment may not try to find a way to cure cancer, this doesn't mean it is not useful. After I performed my experiment, it took me a while to take in all of my results and to figure out how the data I found could be helpful. I began hearing in the news that the populations of both bumblebees and honeybees were declining rapidly; this bee shortage is detrimental to farmers and their crops, as well as to the bees themselves. After I heard that news report, my research went from a lot of graphs and numbers to useful information which could help formulate a plan to increase bee populations. The applications of certain experiments are not always obvious at first, but in the field of science and math, almost everything affects us in some way.

The Experiment:
Do Bumblebees Base Foraging Decisions on Those of Others?

Bees are social insects that rely on other members of their species to provide them with valuable information about food sources. They communicate with each other using various signals in order to indicate the location of a good food source with valuable rewards. In honeybees, the "waggle dance" is used; returning foragers will indicate the quality of a food source and its distance from the hive to the other foragers. By following the directions of others, foragers are more likely to find an adequate flower efficiently and will therefore be more beneficial to the colony.

Much research has been carried out involving the foraging behavior of bumblebees. A major issue that has been addressed in this field has been how bees efficiently choose a flower food source. The goal of my experiment was to discover whether bees use the decisions of other bees in order to make their own decisions. Will a bumblebee choose to land on a certain flower because there is another bee on it or near by? The research was carried out using two approaches: field work and lab experiments.

Many experiments concerning bumblebee behavior have been carried out in a laboratory environment. However, little has been done to study how these results apply to the "real world." The field experiment performed served the purpose of comparing bumblebee behavior in a lab to that in nature. It would seem probable that bees would still have a preference for occupied flowers because a conspecific could be an indication of a valuable food source. By following members of their own species, bumblebees could save time in searching for their own flower (which could be void of nutrients). The lab experiment performed was meant to test whether local enhancement (the attraction of animals to a location currently occupied by another animal) is an adaptation of bumblebees specifically for foraging, or if the attraction between bumblebees also applies in a non-foraging context.

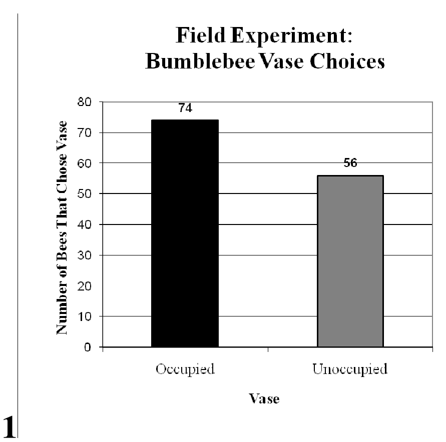
In the field, I hypothesized that bumblebees would more readily land on a flower in a vase occupied by "demonstrator bees" than a flower in a vase filled with unoccupied flowers. Each day, two vases were filled with equal numbers of same species of flower (lavender). One vase was chosen as the occupied vase, and one as the unoccupied. On half of the flowers in the occupied vase, a demonstrator bumblebee (dead *B. terrestris dalmatinus* attached to a pin) was placed. The status of the flower on the first landing of each visitor bee was noted (occupied or unoccupied vase/ occupied or unoccupied flower). Each bee that visited was captured, marked, and returned to the wild in order to ensure that each bee was counted only once.

In the lab, a preliminary training course was necessary before the actual experiment. This course would isolate the "motivated foragers", or the bees that would be most likely to willingly forage during the experiment. All bees were allowed to forage on square yellow plastic chips (2cm x 2cm) at once, some of which contained a reward of sucrose solution. Those who were seen constantly foraging at the yellow chips filled with sucrose were marked and returned to the colony.

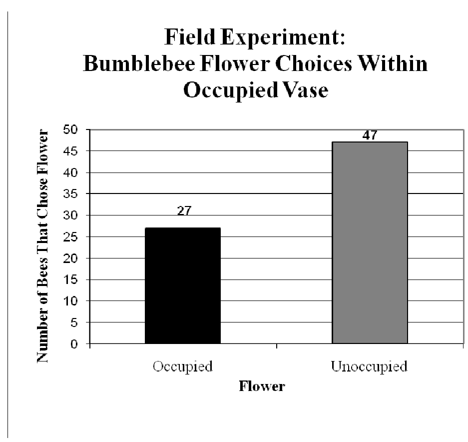
For the first part of the experiment, the arena floor was lined with green paper, and in the center of the floor, a 4 by 5 grid was placed with black duct tape. Ten out of the twenty squares contained a dead conspecific (the squares were chosen randomly and were rearranged for each bee). Bees were tested individually. Each time a bee landed on a grid square, it was noted whether this square was occupied by a dead conspecific or unoccupied. The first ten landings of the bee were recorded; it was then captured and returned to the colony. The arena was cleaned, and the conspecifics were rearranged before each new bee entered.

The second part of the experiment was exactly the same as the first, except that fresh lavender was placed in all twenty squares. Conspecifics were randomly placed on ten of the lavender flowers. The flowers and demonstrator bees were switched, and the arena cleaned before each new bee subject. The purpose of doing two different experiments in the lab was to test whether bees would only follow each other when searching for food, or if they tended to follow each other in a non-foraging context, as well.

The results of the field experiment show bumblebees' trend to land on the occupied vase over the unoccupied vase (Graph 1). Seventy-four out of the 130 bees that visited chose to land on an occupied vase (about 57%). However, a Chi-Squared Goodness of Fit Test did not indicate that this percentage was significant (α=.05, p-value > 0.1 degrees of freedom: 1, Ho π = 65/130, Ha $\pi \neq$ 65/130). The behavior of bumblebees *within* the occupied vase was also studied (Graph 2). It was found that sixty-four percent of bumblebees that landed in the occupied vase chose to land on the unoccupied flower. A Chi-Squared test indicated that this percentage was significant; bees clearly had a preference for the unoccupied flowers in the occupied vases.



Graph 1



Graph 2

In the lab, five B. *canariensis* were able to complete the task. Two landed only on occupied squares, two landed on nine occupied, and the other on seven. A Chi-squared test showed a p-value well under 0.005, so there is significant evidence to prove that in a non-foraging context, bumblebees are attracted to other members of the same species. Three B. *canariensis* completed the task when lavender was introduced, and all landed on an occupied square seven times.

The fact that the bees that landed in the occupied vase generally preferred the unoccupied flowers is very important to the experiment. It is possible that a bee will choose a flower patch based on the abundance of bees, but choose an unoccupied flower within this patch. This way, it would know it was in the vicinity of a good food source, but would not have to feed on a flower that has possibly been drained of all its nutrients by the bee currently occupying it.

Leadbeater and Chittka (2005) have done experiments that prove that bumblebees have a tendency to pick occupied flowers only if they have never been exposed to the species before. This preference usually disappears when bees become familiar with a species of flower, possibly because their own experiences and acquired information about a specific flower's nectar content seem more valuable than clues from other members of their species. It is probable, then, that since the bees in the field experiment were familiar with lavender, they did not need to base their foraging decisions on those of others; they were able to make an individual choice of a certain flower based on previous experience. Since the bees in the lab were bred in captivity, they had no previous familiarity with the lavender flower. These bees are more likely to base their decisions on those of others because the have had no prior experience with these flowers.

Overall, the results from these experiments show that the fact that bees often follow other bees of the same species is not an adaptation specifically to improve foraging. It is more probable that this tendency is a result of bees' general attraction to others. The reason for this habit is unknown and could be an area for further research.

Many plants require the aid of pollinators to maintain their population (National Academies Press). The following could be negatively affected by a decrease in bee populations: flowers (sunflowers), fruits (oranges, tomatoes, melons), vegetables, and beans. If bumblebees do in fact follow other bees, it is possible that introducing a large number of bees to one area could help bees forage more efficiently (instead of having them thinly dispersed). Novice bees could follow experienced bees and help pollinate crops.

This research can be seen as a window to the social systems of other animals. Many species are dependent on each other, and this study provides helpful information about how animals interact with each other.