Experiences with Statistical Consulting

A Senior Project

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by

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Table of Contents

Introduction 3
Initial Goals 4
Project Layout 5
Single Session Projects 6
  Projects 6
  Conclusion for Single Session Projects 13
Multiple Session Projects 14
  Projects 15
  Conclusion for Multiple Session Projects 20
Project on which I did the Analysis 20
Conclusion 22

Introduction

I chose statistical consulting as my senior project for a number of reasons. Practical application has always been the best way to thoroughly understand a subject, as in classes one has a very good idea of what is needed. When a homework assignment covers chapter 9: Chi-Squared tests, there is little doubt as to what procedure will be used throughout. While this may be the best way to introduce a subject, it does not inspire one to answer with confidence when a person asks how to answer a question outside of the classroom setting. Determining interests in aspects of statistics was also important. I felt comfortable ruling out any purely theoretical project, as this requires a different turn of mind, one that constantly enjoys wrestling with the complex math until it yields to simplification. This feeling can be incredibly rewarding in its own way. I have woken at two in the morning with the solution to a statistical problem, scrambling to turn on the lights and write it down should the inspiration prove fleeting. Yet putting my find fully on some problem of this nature requires a peace of mind that I have rarely found when dealing with statistics, and realizing this I chose not to pick a project of that nature. Programming was another alternative that I considered, with the thought that this would look very good on a resume when applying for a job. The importance of fluency in statistical packages was not undersold at Cal Poly, and while I believe this, it seems that it would mostly be important in a job involving programming. Again, there were moments in programming classes when I could understand the appeal, writing that piece of code which solves the problem that has stumped one for so long. The hours in front of a computer are what drive me away. I was very glad that I had the opportunity to take the capstone course, statistical consulting, a year before I was supposed to. Interacting with professionals from other disciplines, learning more about how they work while applying statistical methods provides flexibility in both subject matter and

problem solving style. The consulting class addressed all of the various classes that I had taken, and the stress on explaining these concepts to others less statistically knowledgeable required true understanding rather than the superficial kind made possible by rote memorization. It seemed as though consulting would be a project that could potentially include aspects of the other projects I had considered, which was an added benefit, as I am loathe to write off something I have enjoyed, but I could determine my level of involvement as I saw fit. By this I mean that if assigned a project, it would be likely that I could use the program of my choice, and if I felt that I was still unsure about my feelings toward programming I could use R rather than Minitab.

Initial Goals

My early goal was to gain more confidence in my ability to correctly recognize the statistical method needed for a given problem. Another initial goal was to push myself to use more programming oriented packages to deal with projects I was given. However, the first two quarters that I worked on this project, there were very few clients visiting with the consultant, and my goal became to actually attend enough projects to make a reasonable senior project out of. Luckily, spring quarter brought a multitude of projects, yet this had a severe drawback. Due to miscommunication, I ended up taking 20 units in addition to my senior project during spring quarter. While I managed to have the open consulting hours free, my desire to use R and SAS rather than Minitab disappeared when I was given a simple project to analyze. With the coming of more projects I was also forced to realize how uncomfortable I actually was when it came to correctly assigning the statistical analysis needed for a project. More than that was the problem that many times what the client wanted, or thought they wanted, was not always doable with the data they provided. I realized that consulting in these cases was much more about asking useful

questions in order to not make any large statistical or ethical errors. The consulting course was misleading in this sense, as the clients always knew their data well enough to answer certain questions, and generally something reasonably close to what they wanted could be done. Now this was not entirely unreasonable, as all of the clients in that class admitted to having statisticians design their experiment, or had us design it. The problem was that only one of the clients I saw throughout spring quarter had a statistician design their experiment. To what extent this happens in real world business I do not know, but it seemed that much of our time was given to asking questions about project set up and data collection, so that feasible analytical methods could be perhaps suggested. My overall goal was to learn if there was some aspect of statistics that I could conceivably see myself pursuing in the workforce. This needs some qualification. I have not incurred any debt going to school, statistics was my major, though my parents picked it for me, and my interests have always been broad. I saw no reason to pursue statistics, yet I saw no reason not to either. Therefore, I deemed that the reasonable approach to my senior project was to try to leave it as broad as possible, and try to determine interests and optimal working styles.

Project Layout

I laid out this report in the format that best fit what I learned from consulting. Projects on which I only had a chance to meet with the client once were grouped together, and an introduction and conclusion to these meetings is included. Next I included the projects where I had the opportunity to meet multiple times with the same client, and saw the progression of the meetings throughout the quarter. These projects are also introduced as a whole and a conclusion of what I learned or thought was important for multiple session projects follows the summary of the projects themselves. The last part of the report is the project that I did the analysis for, with a

brief introduction. What follows the section on what I learned from that project is the conclusion to consulting as a senior project, and not just a conclusion to the section.

Single Session Projects

For many projects, I only had a brief chance to learn from the client, as they came in once, or I could only make one of the meetings due to scheduling conflicts. For these meetings, with one notable exception, there was no resolution that I was aware of, so I only had a chance to learn from the client/consultant interaction, as there was never another time to become better acquainted with the data or project. The meetings with clients that Professor Sklar had already met with also resulted in my merely observing the meetings, as I felt uncomfortable trying to give advice when I had not been to all the meetings. What I have realized looking back is that I enjoyed these meetings the most. What I found most interesting and rewarding about consulting was learning to ask better questions. I like the aspect of problem solving, the actual consulting part, but found the statistical aspect of the problems to be what interested me the least. I found it incredibly frustrating to try and figure out how to analyze a client's data when they set up the experiment themselves. This also became more apparent to me in Design and Analysis II, as I found that when one correctly sets up an experiment, analysis becomes far easier. The strongest paradox in statistical consulting had to do with the large number of clients who knew enough about statistics to come up with and run an experiment, yet not enough to analyze their results. Consulting affirmed my fledgling belief that the aspects of the statistics major I enjoyed most were probability, utility, and design.

Projects

Client Name: Dr. Papathakis

Consulting Professor: Professor Sklar

Department: Food Science and Nutrition

Project Type: Observational Study

Project Stage: Analysis

Project Description: This client had collected data on women in Africa at various intervals post pregnancy. These women were in clinics, so data could be collected regularly and reliably. She was interested in nutrient levels in the blood, as fortified flour had been recently introduced. She wanted to detect increases in folic acid, iron, vitamin A, and zinc. The data had missing values, and because it was an observational study, no cause and effect conclusions could be drawn. The women of the study were not all from the same clinics, meaning some women came from more impoverished areas. The implication here was that some of the women may have been getting the allotted daily servings of the flour, while other women may not have been getting as much as was recommended.

How the session went: Proportion tests were suggested as the way to analyze the data in the way she hoped. One could test the proportion of women who were deficient in certain nutrients when they were first tested, and compare this to the proportion of women who were deficient in these nutrients at later periods in the data collection process. As far as I know, no tests were run, and at the end of the session, the client was planning on another meeting.

What I learned: This was the first session I attended, and I made a few notes which I used to try and help shape how I approached this project. I was not very comfortable asking questions, as I did not want to waste the client's time and did not consider myself an expert in statistical procedures despite my time in the statistics major. I wrote down my questions and later asked

Professor Sklar if they were reasonable questions or not. This experience helped determine my level of involvement with clients, as I tried not to ask questions that were not client-oriented.

Client Name: Clif

Consulting Professor: Professor Sklar

Department: Aerospace Engineering

Project Type/Stage: Probability question

Project Description: Clif and a group of other students were trying to get funding for a project in which they would send up 24 cameras into space. These cameras would be evenly spaced in a circle in order to get a panoramic shot. Those who would be providing the funding wanted to be sure that the project was likely to succeed before they went forward, and so Cliff was trying to reassure them. Cliff provided the following information:

The probability for failure for satellites in an 18 year period (the period of interest) was .054. At most three of the satellites could fail in order for the project to succeed. If three failed, they could not be all three next to each other, as this would result in too large of a gap in the picture for the panorama to be considered a success.

How the session went: Professor Sklar and I gathered as much information as we could from Clif, and then told him that we would answer his question as soon as possible. After Clif departed, we proceeded to run through possible ways of handling the question, trying to determine the correct method. Uncertainties remained, and another professor was consulted. Doubt remained and yet another professor was consulted, and the result was an answer that convinced all involved.

What I learned: This was one of the most entertaining projects for me, as probability was an aspect of statistics that I very much enjoyed. Trying to determine how to account for the three in a row failing was the part that was most difficult. Another valuable lesson to learn was never to trust a client's math. Clif may have been an engineer, but he mixed up permutations and combinations when he gave us his numbers. This resulted one part of the probability being off by a factor of 6, which could have proved problematic.

Client Name: Greg

Consulting Professor: Professor Sklar

Department: Biology

Project Type: Observational Study

Project Stage: Analysis

Project Description: Greg was trying to determine if bird populations and species were similar on two adjoining pieces of land in Montana de Oro. Both areas had at one time been pea field, but one piece was now grazed and owned by PG&E. Greg surveyed birds at randomly selected sites on both plots 20 times during a quarter. He could recognize birds by their call, and this is how he determined population. Greg not only wanted to show that the populations were different, but also desired to include the grazed/non-grazed aspect as a variable. He also had other variables in mind that he believed would have an effect on bird populations.

How the session went: Without Greg's data available, it was difficult to know exactly which of the analyses he desired could completed. The only session I was able to attend resulted in better comprehension of the project, but to know the appropriate method to use in analysis required more discussion and the data that Greg had collected.

What I learned: Greg was an interesting client. He showed up about ten minutes late and did not seem very prepared. He was a difficult client not to prejudge, and one had to slow him down once he got going, while getting explicit details from him regarding the data and collection methods was a challenge. I also suffered from a desire to tell Greg his data was not useful, or at least that any conclusions drawn from the data would have to asterisked and reference made to the data collection methods. Determining populations of various species of birds by ear was a method that I struggled to take seriously. I regret that I did not have the opportunity to watch Professor Sklar handle this project to completion, as I would have been curious to see the result.

Client Name: Brittany

Consulting Professor: Professor Sklar

Department: Journalism

Project Type: Survey

Project Stage: Design

Project Description: Brittany was a representative from the journalism department. They were putting together a survey that was intended to yield data regarding student abuse of neuroenhancers. Neuroenhancers are prescription drugs designed to increase concentration, and are generally aimed at such disorders such as ADD and ADHD. However, due to effectiveness as study aids, they are also known to be used illicitly by students and professionals.

How the session went: Professor Sklar and I looked over a draft of the students' survey, to check for problems with questions. There did not seem to be any that would necessarily result in biased answers, but some of the questions did need to have terms within them defined in order to be more explicit. For instance, one of the questions asked whether students had abused

neuroenhancers, yet abuse was not defined. It seemed as though abuse could be defined rather arbitrarily, and Brittany ended up defining abuse as exceeding dosage if the drug was prescribed, or any use at all if the drug was not prescribed.

What I learned: Brittany's project was both interesting and at first seemed fairly straight-forward. Evaluating the questions went smoothly; then Brittany asked about where the journalism department should place the questionnaires and how they should collect them, in order to get a sampling that they could say extended to all Cal Poly students. Here we ran across some difficulties, as Professor Sklar and I both felt that it would be difficult to extend the assumed population beyond Mustang Daily readers. I suggested trying to ask the key questions over Cal Poly portal, yet this would likely not resolve the problem of the target population. This aspect was never fully answered, and I was unable to meet with Brittany again. It seemed that a school sponsored survey would be the only way to address privacy concerns and random selection among the student population.

Client Name: Sam

Consulting Professor: Professor Sklar

Department: Biology

Project Type: Observational Study

Project Stage: Analysis

Project Description: Sam had two goals, which he listed in his grant proposal: to enhance understanding of community succession in Harmful Algal Populations (HABs) and to provide HAB prediction capability using parameters that were measured in the facility he used to gather

data. An algal community was defined as a combination of a minimum of any two species in a single bloom. Sam gathered data 2 days a week for a year.

How the session went: Sam came in asking for us to use ANOVA and Principal Component Analysis on his project. The majority of the meeting went towards understanding his project and defining terms in a way that would be useful to analysis. We discussed problems with various methods that were suggested, and at the end of the session, Sam planned on contacting Professor Sklar again for further discussion.

What I learned: Sam was a client who suggested techniques that he had heard of yet did not understand. The session was given not only to understanding his project and collection methods, but also to explaining why what he desired to do was inappropriate for his data. Clients such as Sam were the most difficult for me, as they required the most off-the-cuff knowledge of statistics.

Client Name: Madeline

Consulting Professor: Professor Sklar

Department: Agriculture

Project Type: Observational Study/ desire for designed study

Project Stage: Design

Project Description: Madeline was trying to design a fecal score rating system that was less arbitrary and more consistent with quantitative tests. In a draft of her proposed system there was a scale with scores going from 0-100 in increments of 25, with each score having a list of descriptive adjectives next to it. For instance, a score of 25 was associated with the following: mixture of formed and unformed, mostly loose. The quantitative measure of dryness was

calculated by weighing the original feces, drying it out in a dehydrator, weighing the dried feces. Using these values, they calculated the percent moisture with the following algorithm:

(Original Mass-Dry Mass/ Original Mass)= % Moisture

Madeline desired to have scores that people assigned feces using her scale correspond well with an assigned percentage moisture interval. An example could be that perhaps at the percentage interval of 0-10% moisture corresponded to a score of 100 and the words formed but very hard.

How the session went: Professor Sklar and I were briefed on the project and on the clients 'desires. How best to approach the project was not determined, if indeed it were possible. The first problem was determining whether people rated the same samples similarly, and to do this did not even seem to be enough. It seemed that the first question would be whether people rated the same specimen the same if they saw it more than once, perhaps on a different background. One could assume that they did, but a sample could conceivably look moister on grass than on sundried dirt, or vice versa. To create a scale that truly corresponded to moisture percentage would require an understanding of how people assigned the scale and well it worked.

Conclusion for Single Session Projects

The projects on which I was only involved in one meeting taught me mostly about the importance of asking good questions. There were many difficulties in these introductory sessions. Although the clients consistently felt that to explain their project would take no more than 10 minutes, without fail this would last most of the session. This was not only due to methods that they used, but to definitions of terms. More preliminary information would be useful, perhaps asking clients for memos which included these pieces of data. Reminding clients to bring the data they had collected with them, and having a computer on hand could also prove useful steps in simplifying sessions.

Multiple Session Projects

For a small number of projects, I was able to sit in on multiple meetings and observe the progress on the project. With one exception, these projects never seemed to have an end. The first meeting generally resulted in a partial understanding of the project and the client's needs, though usually Professor Sklar would either set up another meeting for the near future, or ask the client to email a more formalized set of questions along with the data. The next meeting was given to either further clarifications of the data, or answering the questions about the analysis run. The meetings where Professor Sklar would discuss possible analyses that could be used to answer the clients questions very frustrating, on the client level, though they were very useful in advancing my own understandings of the limits of various analyses. The clients generally felt that knowing the name of a test, and knowing that it was used in previous papers, made them experts on the test and its applications. At this point, I would like to express my admiration for Professor Sklar's patience, not just with these clients, but with me as well. A number of times, I would raise my own uncertainties, which he would then answer, although how helpful this was to the client is debatable. I feel that in the case of a client who was truly there to understand it would be, although in many cases, they just wanted the analysis run so they could be done with their projects. Learning to be sympathetic towards these clients was a struggle for me. What ended up being the best way for me to feel less ill-disposed towards these clients, was remembering what statistics classes they were forced to take as students. The majority seemed to have taken Statistics 251 and/or Statistics 252. I graded for Statistics 251, and I do not remember that class covering design. For that matter, I really did not realize the importance of design until Statistics 423. Design and Analysis I was useful, but the importance of correctly designing an experiment is most easily illustrated by showing the many simple mistakes one can make that result in data being meaningless, not by having students figure out the appropriate

design to answer certain questions about a certain data set. Unfortunately, this reasoning escaped me until after the last project meeting, but better late than never. I would suggest, were it an option, that the importance of design is at least addressed in the introductory statistics courses, using anecdotes such as the ones that Professor McGaughey used. One's hope would be that more students would come to the Statistics Consultant during the design phase of their projects, rather than just the analysis. This would not necessarily result in simple analyses, but it is likely that many mistakes could be avoided. The least frustrating project to work on was the project that was designed in the previous year by the consultant at that time. While the data was not perfect, many of the common mistakes that one came across in other projects were avoided, specifically a lack of replication.

Projects

Client: Kimberly

Consulting Professor: Professor Sklar

Department: Biology

Project Description: Kimberly set up an experiment to investigate the scent preferences of tortoises. There were three scents (ginger, anise, rose) and a control (no smell). Sixteen tortoises were used, and each tortoise was exposed to two scents at a time. Kimberly then waited ten minutes for the tortoise to make a decision. If they did not cross the line in front of either scent, they were marked as no decision. If they did cross the line, this was indicated as a choice of that scent.

How the Project was handled: Professor Sklar first tested for preference of a direction using a simple proportion test and dropping no decision. He next ran six pairwise tests, dropping the

runs where tortoises were exposed to the same scent, when it was found that there was no evidence that Kim's tortoises preferred one direction to another. No decision was again dropped. None of the tests indicated evidence of scent preferences, but this could be because there were 0-2 observations per tortoise, which could have caused problems with independence. Friedman's test was used to check for differences in decisions made by the tortoises. This nonparametric test yielded marginally significant results, indicating that the median number of times a tortoise went left, right, or did not move were not all the same.

What I learned: Kimberly's project was the first project on which I witnessed Professor Sklar discussing the data and the possible analyses for the project with another professor. This was a very eye-opening experience, and it really was one of the defining moments for me throughout this project. The ability to ask questions of a peer is an area that I have struggled in, and I had never really seen this between professors. In retrospect, there have been plenty of times that professors have recommended another professor to me when I have asked a question that they deemed out of their area of expertise, but this was not quite the same thing. The idea of consulting became much more appealing, or at least looking for a job where perhaps you do specialize in some areas, but are constantly exposed to others. Professor Sklar likely would not have to ask another professor questions regarding Multi-variate analysis (I took that class from him), yet when he did have questions, he was surrounded by other experts who were willing to help.

Client: Courtney

Consulting Professor: Professor Sklar

Department: Environmental Engineering

Project Type: Observational Study

Project Stage: Analysis

Project Description: Courtney had collected data on black carbon emissions in Cambria, and hoped to assess variability between different nights on which she had monitors running. Black carbon is created by wood smoke, and wood fires were being regulated in Cambria. She also had data from the MET, which had a number of meteorological measurements from Northern San Luis Obispo, which she hoped to include in model which would explain black carbon variability. Courtney had set up monitors in locations around Cambria to collect her data, and she was hoping to assess variability between monitors as well. On the nights that data had been collected by the monitors, Courtney had driven around Cambria noted the GPS coordinates of the houses that were burning wood fires. She hoped to incorporate distances to the source of carbon emissions, and/or number of houses burning fires as predictors of variability as well.

How the Project was handled: Courtney had a large amount of data. One of the first challenges was to try and make sense of how she had organized it, and Professor Sklar ended up asking her to reformat it in a way that made more sense in terms of the analyses that she desired to run. Her desire to analyze the variability between the monitors was not possible, as she had not placed multiple monitors at the same site, but had rotated them from one placed to the next on different nights. This lack of replication made any statistical analysis impossible for that question. Integrating the MET data with Courtney's data was problematic. The MET data was taken at one location, and the data she had collected about the black carbon emissions were taken at multiple different locations. It was suggested that the average carbon across three monitors be used as the response variable, with some of the MET data used as predictors. Courtney ended up working with Professor Chance, and so the final results of her project are unknown to me.

What I learned: Courtney's project emphasized the importance of replication. It was another project that caused one headaches due to improper design. Most striking about Courtney's project was the point that just because one has a ton of data and many variables of interest to choose from does not mean that the project was well designed. This may seem obvious, but I do think that some people feel as though if you have enough data, some sort of test can be run. I started to feel this way in some of the consulting sessions, but working with Courtney's project disabused me of this notion. Professor Sklar had to explain why certain tests could not be run, and in the end no analysis was run by Professor Sklar, despite the data being rearranged and multiple meetings.

Client: Brittani

Consulting Professor: Professor Sklar

Department: Horticulture

Project Type: Designed Experiment

Project Stage: Data Collection/Analysis

Project Description: Brittani was investigating differences in the establishment of buffalograss cultivars in fine fescues. Her intention was to have the project be a randomized complete block design with three replications. With help from the statistics consultant, she set up three plots of land, each designed to be a replication. Each plot was divided into eight sub-plots, and the eight culitvars of buffalograss were randomly assigned to one of these sub-plots. Each of these sub-plots were further divided into 3 sub-sub-plots, and the 3 fine fescue species were assigned to these sub-sub-plots.

How the Project was handled: Brittani introduced her project in the initial session, defining necessary terms and explaining her null and alternative hypotheses. More clarification and questions came in the second session, especially in terms of future measurements. Brittani's project was ongoing, as some of the buffalograss cultivars were planted as seeds rather than as plugs. So far, she had only been able to gather data on those that were planted as plugs, as the seed cultivars had failed to establish themselves in the fine fescues. Other issues were determining how to measure the success of establishment by the plugs. Brittani suggested a device that would fit over a plot as a grid, so that she could accurately measure the area covered by the cultivars. She also had decided to measure stolen length and radius of plugs. Once measures were decided on, Professor Sklar decided that a linear mixed effects model was the most appropriate way to analyze Brittani's data. He coded this in R and we discussed her results for the data gathered to that point in spring quarter. This model had showed that the interactions between fescues and cultivars were significant predictors of the average radius of the plugs. Brittani was excited to see results, and planned on continuing to meet with the statistical consultant once she had gathered data on the seeded buffalograss cultivars.

What I learned: Brittani was the client who made statistical consulting a good learning experience. The fact that her experiment had been designed by a statistician made analyzing the data to answer her questions feasible. She was open to suggestions and made no claims to understanding which statistical analysis was correct for her data, despite (or perhaps because of) the fact that she had taken more statistics classes than most of our other clients. Her data allowed for more interesting analysis, and because she had experience in various statistical packages, R could be used instead of Minitab, as in this case Minitab might have had difficulties with the analysis. Without having a client such as Brittani, it would have been hard for me to

understand why many of the other clients made the mistakes they made, as I would not have had a model of a well-planned project.

Conclusion for Multiple Session Projects

More than one meeting was generally required to make any sort of headway on a project. In these meetings, I felt that I learned more about actual statistical methods, as I would listen to Professor Sklar try to explain how a test worked in non-technical terms. The big frustrations here involved students who did not understand that results that were not statistically significant were not necessarily useless. Many clients wanted to write the paper saying they had discovered something new in science, that they had discovered a model that could be used or designed an experiment that could be replicated. Unfortunately, due either to poor design or conventional wisdom holding true, many times they were unable to do this. Those who designed their experiment poorly were hard to console. There is not much one can say outside of "Next time come to us first, not last." The clients who had designed experiments in such a way that meaningful conclusions could be drawn from the data were easier to talk with. Even if their alternative hypotheses did not result in statistically significant results, they still were adding to the overall body of knowledge with a study that confirmed, or at least did not disprove, the null hypothesis.

Project on which I did the Analysis

Professor Sklar had me run the analysis on one of the simpler projects that we dealt with. Chris had a project comparing various measures of fitness for swimmers and track athletes. Once Professor Sklar and I established the client's desires, the only real adjustment we had to make was to correct the alpha level at which significance was determined, as Chris wanted multiple tests run. Chris was a very easy client, as he came in for help and wanted to understand

what was being done so that he could explain it in his thesis. We corrected the alpha level using the Bonferroni correction and a familywise error rate of .05. I was given Chris' data, which had measurements from 21 swimmers and 21 water polo players. This was the only project where I was asked to put together the analysis for the client.

Client Name: Chris

Consulting Professor: Professor Sklar

Department: Kinesiology

Project Type: Observational Study

Project Stage: Analysis

Project Description: Chris had collected various measures of fitness on 21 swimmers and 21 track athletes. He was interested in significant differences in these measures, and had hypotheses for each measure.

How the project was handled: Chris had one-sided hypotheses for all of the tests we were to run. An example: Chris predicted that percent body fat in the legs of swimmers would be higher than that of runners. This allowed for simple tests in Minitab to be run, though as I stated in the introduction, two measured were tested using nonparametric methods. I ran normality tests on both sets of data, and determined that there was evidence of non-normality in two of the measurements for swimmers. I therefore used the Mann-Whitney test when comparing these measurements to the runners, as this non-parametric test is similar to the two-sample t-test that I was using for the normal data. I included the p-values and the graphs displaying normality.

What I learned: This project, while having a very straight-forward analyses, was still challenging to some extent. Initially I ran two-sided tests, yet I thought about it, and decided to

ask Chris if he had some idea of which group would have higher average values for the different measures. He did, and I ran those. Another challenge with analysis was the evidence of non-normality for two of the measure in the swimmer group. I talked with Professor Sklar, as initially I was not sure what the best approach was. I considered a transformation, but that seemed unnecessarily difficult, and Professor Sklar suggested the Mann-Whitney test. Looking into the test, out of curiosity and in order to capably present my findings to Chris, I found that this test allows one to test data in a similar manner to the two-sample t test, yet the requirement of normality is not needed. Presenting the findings to Chris was another experience that I learned from. The most important lesson I took away was to review your own presentation thoroughly and be consistent in ordering. I arranged the paper in the way that made the most sense to me, which meant that I put the four two sample t-tests together, and then put the two Mann-Whitney tests together at the end. However, the alternative hypotheses were set-up in the order that Chris sent them to me, and the graphs of normality were in this order as well. Professor Sklar asked a question about the second two-sample t test, as it looked to him as though I had tested the wrong alternative hypothesis, in fact getting it backwards and getting significant results. This hung me up for a minute, as I had double and triple-checked my work, and could not believe I had done that. After looking over the results more than once, I realized that the second test actually corresponded to the third alternative hypothesis, as the data for the measure in the second hypothesis showed evidence of non-normality. This could easily have been avoided if I had ordered all graphs, hypotheses, and results in a consistent fashion.

Conclusion

In assessing the success of my goals for the senior project experience, I feel reasonably satisfied. While I still am not fluent with diagnosing projects that come in from any client, I am

comfortable with the simpler ones, such as tests of proportions. I also have recognized that in some cases, it takes a significant amount of research to determine the best method of analysis, due to methods used in collecting the data. This became apparent not only through senior project, but also through Design and Analysis II and tutoring, which I did over the summer. But the experiences in senior project were the most influential on this way of thinking. Before this project, I assumed the professors in the department were omniscient in the way of statistics, and that any problem put before them was promptly answered correctly. While this may be for the most part true, at least in the case of class-related problems, I have seen that some projects have no easy answer, or that they have more than one, and which is best is not immediately apparent, as little differences in design and tests desired will influence how the data is analyzed.

What I gained was not the ability to recognize the best way of handling any given project, but an understanding that I had not hitherto had about cooperation. I have always been strongly opposed to group work, as I have felt that one person almost always does the bulk of the work, it just depends on who has the most at stake. While this still holds in a classroom environment, the professional academic setting has a much stronger appeal after watching it in action. I am still curious about the workforce outside of academia, and my suspicion is that it more closely resembles the classroom, due to performance-based incentives. I do not believe that this promotes true cooperation, as the gain of one is the loss of another.

Working on the write-up for this project has provided more insight in the way of personal motivations than attending the consulting sessions. This is due mainly to rereading what I have written and a desire to eliminate as much sarcasm and intolerance as possible. My initial take on students who came in after designing their own experiment was not remotely understanding or compassionate. Only when trying to revise my writing was I forced to analyze the situation so

that I could write more kindly, but at the same time still truthfully. When writing about what motivated the choice of consulting, the revisions required to not sound dismissive of certain aspects of statistics again required more thought than I had previously spent. My feelings towards purely theoretical statistics were that they required a mind that placed math first and foremost, with all other aspects of life coming in a distant second. There is no doubting the intelligence of such individuals, yet to me I wondered about the sense of happiness that one could obtain from placing such an emphasis on math. When trying to sound more respectful towards those who work with the theory of statistics, I realized that I do remember incidents where I had felt a profound sense of accomplishment and joy at solving a problem that came from the classes which were more theory based. This goes for programming as well.

I have not yet decided what the next step is in my life. The question of whether or not I could pursue statistics in the workforce I can at best answer with a yes that I will qualify. Design is the area that I find most appealing, and this is due in large part to Professor McGaughy's terrific class, and in part to the numerous frustrations I came across during my senior project. It seems as though design would be the field in which problems are resolved earlier rather than later. The focus is on gathering good data with what one has, rather than analyzing data as best as one can. When I see studies in the news or in books, I am always skeptical of results, and desire to understand the methodology implemented in the collection and analysis of the data. I think that once I understood better the design and analysis behind the various studies done, I would be more curious about the theory, and perhaps then I could pursue that area of statistics. Though I am undecided at this point, design is the area I would most like to pursue. I would like to thank Professor Sklar for his time and help, and the statistics department for the overall experience.