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South Dakota State University

JOURNAL OF UNDERGRADUATE RESEARCH

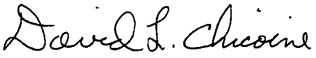
Volume 5 • 2007

FOREWORD

Since its foundation in 1881, South Dakota State University has had a rich history of research, both at the graduate and undergraduate level. It is my pleasure to write the forward to the 2007 edition of the South Dakota State Journal of Undergraduate Research. This journal along with Undergraduate Research, Scholarship, and Creative Activity Day (U.R.S.C.A.D.) showcase the quality of undergraduate research at South Dakota State University.

The importance of undergraduate research opportunities has long been recognized. Traditional learning in the classroom teaches students the existing knowledge in each discipline. But undergraduate research gives students the opportunity to contribute to and expand the existing body of knowledge. Countless professional and research careers have been born by students being given the opportunity to do original research on a subject which was already a fascination. As we work together to strengthen the research capacity of South Dakota State University, one of my goals as President is to increase research opportunities for undergraduate students, along with their graduate counterparts at this great university.

Congratulations to each of the students whose research is published in this edition of the South Dakota State Journal of Undergraduate Research. Our entire academic community recognizes your research contributions.



David L. Chicoine, Ph.D.
President, South Dakota State University

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SDSU Journal of Undergraduate Research

(Next deadline for submission: June 1, 2008)

MANUSCRIPT SUBMISSION

This section is intended to provide you with some guidance regarding the final structure and format your research manuscript should possess to warrant publication in the *SDSU Journal of Undergraduate Research*. Student authors wishing to have their work published in the *Journal* are advised to follow these guidelines as closely as possible, as manuscripts submitted to the *Journal* that are not of high quality in content and format may be rejected by the editor. The *Journal* editor understands that research products and manuscripts from different disciplines may take on quite different forms. As such, if these guidelines do not adequately answer your questions, simply follow the format and guidelines utilized by a major scholarly journal in your field of study. Professional journal articles in your field of study are a guideline for manuscript length. (When in doubt, article conciseness is important.) Your faculty mentor should be able to advise you in this regard.

All manuscripts must be submitted by your faculty mentor to the *Journal of Undergraduate Research*, Administration Building, Room 130. **E-mail electronic versions** to Linda.Winkler@sdstate.edu by June 1, 2008. Manuscripts submitted by students will not be accepted for publication.

TECHNICAL GUIDELINES

Your *Journal* manuscript must be submitted both in hard copy (printed) form **AND** electronic format (via e-mail).

1. **HARD COPY SUBMISSION** Use Microsoft Word® to prepare, print and submit your manuscript with all graphics, figures and captions in place, exactly as you would like to see them appear in the final *Journal* article. Every effort will be made to reproduce your manuscript in a form most closely resembling your hard copy, however, slight variations may occur in converting your files to those used by the publisher. **Your careful adherence to the information in the next few paragraphs will ensure that your manuscript is reproduced with minimal errors.**

2. **ELECTRONIC SUBMISSION** Submit your Microsoft Word® file and all graphic and photo files as attachments to the *Journal* e-mail address. Sending one e-mail message with multiple attachments is preferred over several separate e-mails. **Manuscripts with special characters and/or symbols must also be provided in a pdf file of the highest-possible resolution with the fonts embedded.**

   All graphics (artwork, photos, graphs) **must be submitted as separate files**, saved in EPS, TIF or JPG format with a resolution of no less than 300 dpi (dots per inch) for optimum quality reproduction. The graphics will be inserted into the positions within your article as you've specified on the hard copy. Microsoft Publisher files cannot be translated and, therefore, will not be accepted.

By default, the *Journal* will be reproduced in black and white. Color printing is available, at the expense of the author, for those who have graphics they would like to portray in color. Cost of color printing is approximately $50 per page.

If you have further questions about submission, or if additional questions about content and format arise, please do not hesitate to contact the *Journal* editor, George Langelett, Economics Department, 688-4865 or George.Langelett@sdstate.edu.

MANUSCRIPT REVIEW

After your manuscript has been submitted to the *SDSU Journal of Undergraduate Research*, it will be reviewed by the editorial staff, and, if deemed acceptable for publication, converted into a "publication-ready" format (proof). A hard copy of the manuscript proof will then be returned to your faculty mentor by July 1 for final review. At that time, it will be your mentor's responsibility to make any final changes to the document and return it to the editors by the noted deadline (July 15).

It is imperative that all proofs be returned to the *Journal* staff in a timely manner so that any final changes can be incorporated before the volume goes to press.

FINAL PRODUCT

The final form of your paper will depend greatly on the nature of your topic and certain publishing conventions that may exist within your discipline. It is expected that the faculty advisor for each project will provide substantial guidance in this matter. An excellent general resource providing details of the content, style and organization of a typical journal article is the *Publication Manual of the American Psychological Association*, which is accepted as a definitive source in many disciplines. While the emphasis there is on empirical research reports (based upon original research and data collection), other types of papers are also described (review articles, theoretical articles), and an appendix: "Material Other Than Journal Articles," may be useful.

Your discipline may have its own publication style preferences, and you should explore this matter with your faculty advisor. For most all disciplines, however, articles should follow a standard format and begin with a descriptive title, the name of the author(s), the name(s) of the faculty advisor(s) and an abstract describing in brief the purpose, methodology and findings or conclusions of the project (see below). Manuscripts describing empirical research will typically be organized into further subsections, labeled: Introduction, Method, Results, Discussion, (or variations on those subheadings), along with a complete list of References.

The rest of these guidelines are intended to provide you with a sense of the appearance and content of a typical final research report, as it should appear in the *SDSU JUR*. Beginning with "Title of Your Article" below, the remainder of this document is written in the *SDSU JUR* style. Please note font sizes, format and section content, and use this example to guide you.

*** Sample Format ***
Title Of Your Article
Author(s): Your Name, Your Partner's Name(s)
Faculty Sponsor: Faculty Mentor's Name
Department: Economics

ABSTRACT

This will be a brief statement of what was done in your research, along with your principal results and conclusions. Only the most important facts should be related here, in nonindented paragraph form. Offset the abstract by using margins that are indented 0.5" on each side relative to the body of your manuscript. You may list key words to aid in online computer-search applications, if that is appropriate. For example, **Keywords**: undergraduate research, manuscript, submission, guidelines.

INTRODUCTION

This is the first formal section of a research report. This and the sections to follow should be single-spaced and laser-printed on only one side of the paper (8.5" x 11"). Early in this section, provide a general description of the research problem or activity. Attempt to identify and define whatever terms your reader will need to understand your project. The remaining paragraphs are often used to summarize relevant findings from previously completed research. Always be sure to cite your sources. Sarbin and Coe (1969) state that "in preparing a . . . report, the student must pay careful attention to the problems of documentation." In these examples of citations, "the documentation is contained in the parentheses . . ." (Sarbin and Coe, 1969). To find the remaining information, the reader examines the reference list at the end of the paper. This citation style is sometimes called "scientific notation." Other citation styles may be more appropriate to your own disciplines. Be sure to be consistent and to discuss this with your faculty advisor. Ultimately, you should use a citation style that is commonly accepted within your discipline.

The last portion of an introduction is often used to state the specific expected outcomes of the project; sometimes this appears as one or more formal testable hypotheses.

METHODS

The content of this subsection may vary greatly, depending upon the nature of the research project. You should refer to publication manuals or published research for information specific to your type of project. Sometimes this subsection is labeled "Materials and Method." Figures (see below) are often used to clarify and explain important details. In general you should use this subsection to explain to your reader, in as clear a way as possible, what you did, in the order that you did it. In an empirical research report, you should try to provide enough detail that another researcher could essentially duplicate your study without referring excessively to other sources.

RESULTS

This should be a clear description of any data (or other material) generated as a result of your research. It must start out as a written description, but this subsection is often supplemented with FIGURES and TABLES, or PLATES, or other types of graphic images. These are never sufficient by themselves. Figures and Tables should not appear in your paper until after they've been mentioned or referred to in the written portion of this section. They should appear as soon as is reasonable after such mention, either on the same page, or on the next page (see Figure 1, and Table 1). Notice, in particular, that in most scientific papers, the number and title of a Table appear above the data being described, but the number and title of a Figure appear below the data. Any units of measure must appear either in the title, or independently in the column or row headings. A table is useless unless the reader can understand exactly what is represented. **Graphic materials, properly labeled, should be included IN THE BODY of your paper, not grouped at the end.** (See the above section labeled "Submission" for further details.)

The Results section is also the place to include any statistical interpretation of the data, if such exists. Be sure to point out any important features of your findings, but AVOID to the extent possible, any THEORETICAL INTERPRETATION unless you are combining this with the next section (DISCUSSION or CONCLUSIONS).

DISCUSSION (AND/OR CONCLUSIONS)

This section is sometimes combined with the previous RESULTS section, especially when that permits a more efficient presentation. Your "Discussion" should include any theoretical interpretation of your data, including, when appropriate to your topic, the following: (1) WHETHER your results support any specific hypothesis or hypotheses you may have stated in your introduction; (2) HOW your results compare with the results in your cited research sources; and

(3) WHAT theories or explanations seem to best explain or account for the results that you are describing.

Again, be sure to cite (Sarbin and Coe, 1969) the sources for theoretical ideas and explanations provided by other writers or sources. Also, address whether there any practical applications for the results or methods used in your research.

LIMITATIONS

It is often useful, particularly in undergraduate research, to provide a summary of the limitations of the research from methodological, theoretical or other points of view to provide perspective and to serve as a possible basis for improvements in future projects.

ACKNOWLEDGEMENTS

Feel free to use this section to BRIEFLY acknowledge any and all who helped you bring your project through to fruition. You may also thank any funding sources if appropriate.

REFERENCES

Provide a complete list of all cited materials in a format that is consistent with publications in your area of study.

APPENDIX

This section is optional and generally unnecessary. In some cases, it may be included to provide a more complete description of materials used. The editor of the *SDSU Journal of Undergraduate Research* would prefer that no appendices be used. However, if absolutely necessary, the number of pages in an appendix should be kept to an absolute minimum!

The Journal of Undergraduate Research would like to thank Dr. Kevin Kephart, Vice President for Research, and Dr. Michael Reger, Executive Vice President for Administration, for their efforts to secure funding for the Journal.

Low-Sugar Bread Formulations Using Alice, A Hard White Winter Wheat

Authors: Jessica Saunders and Sara Stauffer
Faculty Sponsor: Dr. Padmanaban Krishnan
Department: Nutrition, Food Science and Hospitality

ABSTRACT

Alice white wheat is a new cultivar of white wheat that has many desirable attributes for the baking industry. Its main appeal is the reduction in bittering compounds and pigments. White wheat is in demand in the booming Asian noodle market. The purpose of this study was to analyze rheological properties of white wheat flours using the Mixolab, a state of the art dough rheology instrument. Additional objectives included sensory testing of various reduced-sugar bread formulations and the determination of physico-chemical properties of flours and of bread made with them. Experimental baking using standardized methods revealed that sugar levels could be reduced by half and yet yield acceptable loaves of bread. This was possible owing to the reduced levels of phenolic compounds in white wheat. Such compounds mask the sweeteness perception of breads made when hard red wheat is used. Acceptable loaves of bread were produced with Alice flour and Alice whole wheat flour as judged by evaluation of bread characteristics. Loaf height, crumb structure, crust color and other bread characteristics were also acceptable by objective and subjective standards.

INTRODUCTION

Alice is a new variety of Hard White Winter wheat developed by wheat breeder Dr. Amir Ibrahim, South Dakota State University. This variety shows promise for use in bread baking and noodle production. It is named to honor Alice Wright, an Administrative Assistant for the South Dakota Wheat Commission. This new variety of wheat is derived from the cross 'Abilene'/'Karl' grains. It has the following desirable traits: white grain color, earliness, good bread baking qualities, good pre-harvest sprouting tolerance, and high yield in rain fed systems.

Hard red wheat is the primary choice for loaf breads in the United States. White wheat lacks certain pigments found in red wheat that are bitter tasting. Baked goods made with white wheat appear to exhibit enhanced sweetness. Sugar levels in recipes need to be adjusted to compensate for the lowered bitter tastes. Reduction of sugars may show a potential for lowered caloric content if bread-baking functionality is not adversely affected.

In testing a new economic class of wheat for bread baking qualities, it is necessary to address the quality factors of interest to the commercial baker. The quality factors involved in bread baking include water absorption, mixing time, dough characteristics,

fermentation tolerance, and physical appearance in the baked loaf (i.e., volume, crust color, and crumb). Use of the Mixolab provides information on the dough such as water absorption, dough stability, optimal mixing time, and tolerance to over-mixing.

A traditional test for the protein quality in a wheat variety is the measurement of a bread density or loaf volume to loaf weight ratio. Wheat contains gluten proteins, which contribute to the formation of the dough upon addition of water and physical manipulation. During the process of bread baking, the gluten matrix traps carbon dioxide produced by the yeast and allows the dough to expand. This expansion is translated into "oven spring" and measured as loaf height. Comparing the height to volume ratio against breads made with standard flours will give a good indication of protein quality.

The Mixolab is also able to determine protein quality by measuring the mixing tolerance. It is a tool that allows the analysis of the quality of the protein network, starch behavior, and enzyme activity of flours. In addition, the instrument measures and records the resistance of the dough to mixing in real time while at the same time monitoring bowl and dough temperature as well as mixing torque. The dough is manipulated between blades and mixing torque is monitored. The parameter is monitored through kneading and heating. Peak time is the optimal dough development time and mixing tolerance is the resistances of dough to breakdown during continued mixing (Wheat and Flour Testing Methods, 2004). Both parameters are functions monitored by the Mixolab. The instrument is thus a valuable tool for the determination of grain quality and prediction of baking functionality. Baking functionality in turn determines end products that can be produced. Protein content is a major nutritional constituent that dictates water absorption, texture, appearance, and gluten strength. Gluten is developed when flour is moistened and physically manipulated. The gluten imparts elasticity and extensibility characteristics to the dough. Weak gluten results in shortened peak times and less mixing tolerance than strong gluten flour. White wheat (7-10% protein) is one of five wheat classes which includes hard red spring wheat (11-18% protein) used for bread and blending; hard red winter wheat (10-15% protein) used in bread products; soft red wheat (8-12% protein) used in cakes, cookies, and crackers; and durum (11-16% protein) used in pasta products (D'Appolonia, 1987). Lower protein contents are good for tender products such as snack cakes, while higher protein content provides a chewy baked product like French breads (Wheat and Flour Testing Methods, 2004).

MATERIALS AND METHODS

Experimental Baking

A straight dough baking procedure was employed where all ingredients were mixed in one stage. Ingredients were added to the bread maker in the following order and amounts: distilled water (180 ml); vegetable oil (14.18 g); egg (50 g); salt (14.29g); sugar (28.5 g); Alice flour or Alice whole wheat flour (300 g), bread flour or all-purpose flour (270 g). The vegetable oil, eggs, sugar, bread flour and all-purpose flour were commercial products that were locally purchased. Alice wheat and Alice flour were acquired from the South Dakota Foundation Seed Stocks Division (Plant Science Department, South Dakota

State University, Brookings, SD). Alice whole-wheat was ground to produce whole-wheat flour using a laboratory mill (Retsch Centrifugal Mill, ZVM-1, 0.5 mm mesh). One pound loaves of bread were baked in a West Bend Bread Maker (The West Bend Company). Bread loaves were baked in duplicate for each treatment. The treatments were given the following labels: Alice Flour Standard Sugar (AFSS), Alice Flour Low Sugar (AFLS), Alice Whole-Wheat Flour Standard Sugar (AWSS), Alice Whole-Wheat Flour Low Sugar (AWLS), All-Purpose Flour Standard Sugar (APSS), and All-Purpose Low Sugar (APLS). A loaf using a standard sugar recipe and bread wheat flour was utilized as the control. Low sugar formulations and standard formulations employed one and two tablespoons of sugar, respectively.

Measuring Bread Height

Bread loaf height was measured using a standard metric ruler and read at the loaf peak. Loaf volume did not need to be calculated since the cross-sectional area of all loaves was uniform and conformed to the dimensions of the same loaf pan used for all loaves. The use of the same bread machine and bread pan removed variability due to baking technique.

Sensory Tests

A triangle test of difference was used panelists to discern sweetness differences. In this test three samples (two similar and one dissimilar) were administered to determine if panelists were able to pick out the odd sample. Preference tests were conducted to evaluate overall liking of breads. Samples were ranked by preference in the latter test.

Moisture Analysis

The Moisture Air Oven Method (AACC 44-16) was followed for moisture content on each flour sample. Samples were dried for 1 hour at 130°C.

Protein Analysis

Protein determination was completed using the CE Elantech Flash EA 1112 (ThermoFinnigan Italia S.p.A., Rodano, Italy) following the Dumas combustion method (AACC 46-30). Percent nitrogen was converted to percent protein using a factor of 5.7 specific for wheat flour (% Protein= % Nitrogen X 5.7).

Mixolab

Dough rheology tests were done using manufacturer's instructions. Flour water absorption or optimal water needed to make the dough was determined from the mixolab curve. The Mixolab was programmed to simulate a mixing profile similar to the Farinograph (Brabender Instruments, New Jersey) for the first eight minutes of each sample run. Key pieces of data relevant to dough mixing requirements such as water requirement, dough mixing time, dough stability and mixing tolerance were derived from the Mixolab curves. Beyond 8 minutes the heating and cooling phases were designed to bring out the differences between flours under real world baking conditions. Such tests that exaggerate differences between flours serve to provide explantions for baking performance differences. Such differences are due to starch-protein interactions, enzyme

activity and other varietal and environmental factors. Five distinct phases have been identified by the manufacturers of the instrument. These will be discussed in a later section.

RESULTS AND DISCUSSION

Bread Height

The control (bread machine flour) produced loaves with the highest height (18.0 cm). AFSS produced a loaf slightly lower in height (17.1 cm). The reduced sugar loaves contributed to smaller loaves. AWLS loaf produced the smallest loaf height (12.8cm). This is likely due to the inclusion of the bran and germ. Alice flour produced a shorter loaf height when compared to the bread flour loaf. This is most likely due to a lower amount of protein in the Alice flour. Table 1 below shows the compilation of loaf heights.

Flour type	Loaf Height in centimeters	
	Standard	Half Sugar
Alice Flour	17.1 cm	15.3 cm
Alice Whole Wheat Flour	14.0 cm	12.8 cm
Bread Machine Flour	18.0 cm	--
All-Purpose Flour	15.0 cm	14.5 cm

Table 1. Bread loaf height

Sensory Tests

A triangle test is a discriminating test that presents the sensory panelist with three coded samples. Two of the three samples are the same product; therefore it is the panelist's job to pick out the odd or dissimilar sample. In the triangle test between bread samples made from AFSS and AFLS, the panelists were unable to determine a difference in sweetness as only 12.5% of panelists correctly identified the different bread sample (Table 2). This is valuable as it illustrates that differences in sweetness is not perceived in bread made with Alice flour using one or two tablespoons of sugar in the formula. In a triangle test using bread samples made from AWSS and AWLS, the panel was once again unable to determine a difference in sweetness because only 25% of panelists correctly identified the different bread sample (Table 3). This test showed the same inability of panelists to discern the differences when regular and low sugar recipies were tested. A preference test allows the panelists to rank in order of most liked to least liked sample products. In a preference test between bread made with AFSS, AFLS, and bread machine flour, half of panelists preferred AFSS and half preferred bread machine flour equally (Table 4). Preference test panelists chose standard sugar bread when they were presented

with a choice. Alice flour and bread machine flour were equally liked by the sensory panelists. The sensory panel consisted of 3 males and 3 females with backgrounds in food science.

Code Number	Recipe	Number of times chosen
543	Standard Sugar	2
921	Standard Sugar	5
722	Low-Sugar	1

Table 2. Triangle Test results for Whole Alice Flour Bread

Code Number	Recipe	Number of times chosen
305	Standard Sugar	2
281	Low-Sugar	1
947	Low-Sugar	5

Table 3. Triangle Test Results for Alice Wheat Flour Bread

Alice Flour vs. Bread Flour Preference Test Results

Bread	Alice flour Standard Recipe	Alice flour Low Sugar	Bread flour Standard Recipe
Code Number	642	875	563
Most Preferred	4	0	4
Middle	4	1	3
Least Preferred	0	7	1

Table 4. Preference Test Results

Moisture Content

Alice flour was found to have the lowest moisture content (10.4%), although there was very little difference between the remaining flours (Alice whole wheat 11.3%; bread flour 11.7%, all-purpose 11.6%). The moisture content of the flour was necessary for the determination of total water requirements of the dough.

Protein Analysis

Commercial bread machine flour contained the highest amount of protein (16.9%). Alice flour and Alice whole wheat flour were closer in protein content at 15.0% and 15.7%, respectively. All-purpose flour had significantly lower protein content than the other flours at 14.1%.

Flour	Moisture Content %	Protein Content %
Alice Flour	10.4	15.0
Alice Whole Wheat Flour	11.3	15.7
Bread Machine Flour	11.6	16.9
All-Purpose Flour	11.6	14.1

Table 5. Moisture and protein content of wheat flours

Mixolab

The key principle of the Mixolab is that it examines the characteristics of the rheological behavior (hydration capacity, development time, etc) of dough as a function of mixing and temperature. Torque produced when the dough is kneaded between specially designed mixing blades is measured in real time. Other parameters measured included protein reduction, enzymatic activity, gelatinization, and gelling of starch.

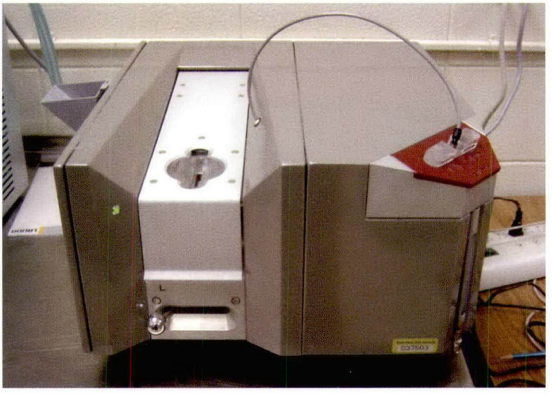

Figure 1. Chopin Mixolab

Figure 2 shows a Mixolab profile of several different flours. Arrows illustrate bowl temperature curve and dough temperature curve. Three flour curves are superimposed and color contrasted onto one graph allowing for easy comparison.

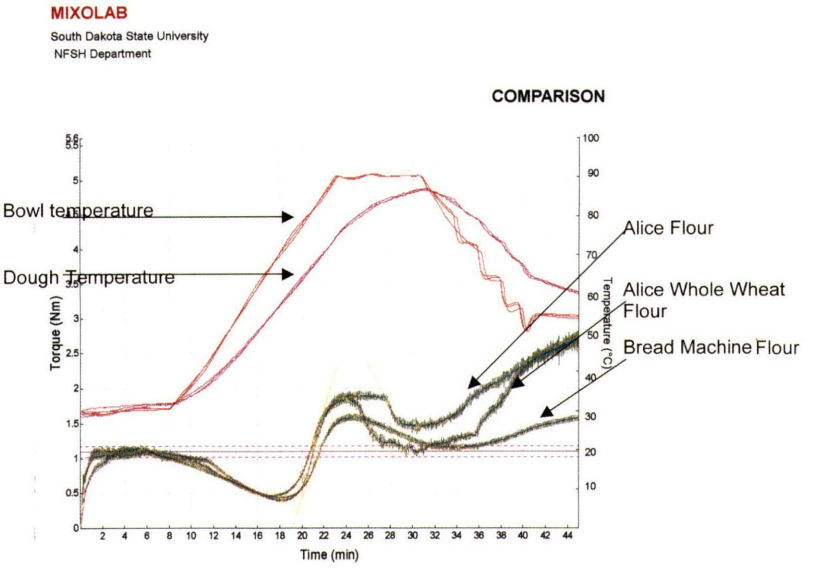

Figure 2. Mixolab Curve

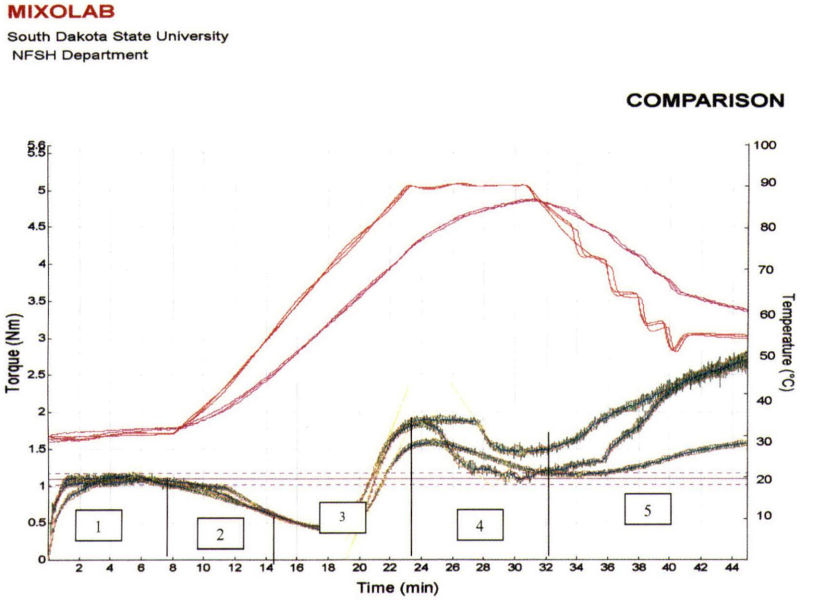

Figure 3. Breakdown of steps in Mixolab curve

Type of Flour	Alpha	Beta	Gamma
	Nm/min	Nm/min	Nm/min
Alice Flour	-0.04	0.514	-0.304
Alice Whole-Wheat Flour	-0.06	0.588	-0.172
Bread Flour	-0.132	0.424	-0.066

Table 6. Rhelogical Dough Comparison. Units are expressed as torque.

Information provided in Table 6 above shows that for protein reduction (alpha), bread flour had the greatest decrease in slope, indicating a higher protein quality when compared to Alice Flours. Based on starch gelatinization (beta) qualities, Alice Whole-Wheat had the greatest increase in slope indicating greater gelatinization and consistency in the starch. Analyzing amylasic activity (gamma) revealed that Alice Flour had the sharpest decrease in slope indicating greater amylasic activity. Implications of gamma values are the subject of basic research and will reveal additional functional traits that are yet to be exploited in wheat flour evaluation.

Bread machine flour had the highest water absorption (62.4%) followed by Alice Whole-Wheat (60%) and Alice Flour (57.8%). Higher amounts of protein in flour result in increased water absorbance and higher moisture requirements in the dough. Water is a relatively inexpensive ingredient that is maximized in bread formulations.

Mixolab results were presented in the form of a graph that provides five important pieces of information. Figure 3 provides a visual image identifying the various phases.
1.) Development: water absorption capacities are determined and dough mixing characteristics are measured
2.) Protein reduction (alpha): As dough temperature increases, consistency decreases; protein quality is determined by the intensity of the decrease of consistency.
3.) Starch gelatinization (beta): In this phase gelatinization becomes dominant and an increase in consistency is observed
4.) Amylasic activity (gamma): The value at the end of the plateau depends on the endogenous activity; a decrease in consistency represents a greater amylasic activity
5.) Starch gelling: At this stage, cooling starch retreats and increases product consistency. (Chopin Mixolab Manual 4/2005)

CONCLUSION

Alice white wheat is a new wheat variety of white wheat that has many desirable characteristics such as white grain color, earliness, decreased quantity of bittering compounds, and good baking functionalities. One major appeal of this grain is the reduced quantities of sugar that can be used in bread loaf formulation, thus resulting in a lower calorie and carbohydrate-containing product. This would be ideal for individuals who require dietary reduction of sugar.

Sensory analysis panelists were unable to discern differences in sweetness between breads made with Alice wheat and other wheat flour when sugar was cut back in the formulation. Sugar levels did contribute to greater expansion of loaves made with

standard sugar (even Alice flour) in the formula than those with reduced sugar. This aesthetic difference in loaves and bread slices appears to have influenced panelists who ranked their preference for the various breads.

Objective and subjective evaluation of bread made from standard sugar and reduced sugar formulas revealed that bread produced with Alice flour has many desirable baking attributes as judged by crumb structure, crust color, loaf volume, oven rise, symmetry and internal texture.

REFERENCES

AACC Method 44-15A, Moisture Air Oven Method.

Approved Methods of the American Association of Cereal Chemists. 10th ed. The Association, St. Paul, MN, 2000.

Chopin Mixolab Manual. 4/2005

BertL.D' Appolonia. 1987. Factors Involved in the Quality of Bread Wheats. Chapter 9 in Cereals and Legumes in the Food Supply, edited by Jaquelin Dupont and Elizabeth M. Osman. Iowa State University Press, Ames, Iowa 50010.

Wheat and Flour Testing Methods: A Guide to Understanding Wheat and Flour Quality. 2004. Wheat Marketing Center, Inc. Portland, Oregon

ACKNOWLEDGEMENTS

The authors wish to thank the SD Wheat Commission, SD, Crop Improvement Association, SD Foundation Seeds, SDSU Plant Science Department, and the SD Agricultural Experiment Station for their support of this research.

Variety "Expedition"
Hard Red Winter Wheat

Variety "Alice"
Hard White Winter Wheat

Dust Emission from South Dakota Cattle Feedlots

Author: Rick Weber
Faculty Sponsor: Dr. Richard Nicolai
Department: Agricultural and BioSystems Engineering

ABSTRACT

Dust and particle emissions (PM) from cattle feedlots is a concern for producers in order to maintain good relations with neighbors and also to comply with the EPA proposed $PM_{2.5}$ particulate emission rules. Dust at 2.5 microns, which cannot be seen by the naked eye, is a potential health hazard since it can be ingested into the lungs of humans. One of the proposed regulations of the Federal Clean Air Act is to apply the $PM_{2.5}$ standard to the agricultural sector. This research project examines the particulate matter dust emissions of various sizes in microns including 2.5, 10, and total particulate matter emitted from a typical cattle feedlot in eastern South Dakota. The particulate matter from ambient air on the feedlot was monitored for a period of four weeks in August 2005 to obtain a large sample and accurate results. The data was then analyzed and interpreted into micrograms per cubic meter for comparison with various EPA standards and tests. The results from the feedlot show that during optimum dust production conditions (high temperatures, low humidity, calm winds, and low precipitation) feedlots can produce significant levels of particulate matter at the 2.5 and 10 micron sizes. These levels are similar in significance to the National Ambient Air Quality Standards. The findings from the research may assist County Zoning Boards and Commissioners with information to assess dust and particulate matter potential from livestock operations. This data found may also help lawmakers effectively make decisions on the regulation of feedlot operations rather than blindly inhibiting their operation.

INTRODUCTION

This research project, the first of its kind in South Dakota, measures $PM_{2.5}$, PM_{10} and total particulate matter (PM_{TSP}) produced from a cattle feedlot in eastern South Dakota. Particulate matter (PM) is the general term used for a mixture of solid particles and liquid droplets found in the air.(EPA Report, 34) Particulate matter includes both coarse (PM_{10}) and very fine dust particles ($PM_{2.5}$), which cannot be identified by the naked eye, can potentially cause health issues. Exposure to coarse particles is primarily associated with aggravation of respiratory systems such as asthma while exposure to fine particles is associated with decreased lung function, increased hospital visits, and increased respiratory symptoms and disease (Tomany, 21). The Environmental Protection Agency

(EPA) has proposed standards of 15 μg/m³ for $PM_{2.5}$ emissions and 50 μg/m³ for PM_{10} emissions (EPA Report, 35). The livestock industry has been identified as a potential producer of these emissions. The data collected in this research will be compared to the standards to determine the relationship between typical dust production levels from a feedlot and the proposed standard.

The livestock industry accounts for 1.6 billion dollars of annual revenue in South Dakota, 34% of the total farm receipts (ERS 2005). Increased livestock production provides competitive local grain markets, increased returns due to decreased basis levels, and more readily available manure for fertilizer applications. These all encourage and improve the economy in South Dakota.

This research study provides regulators with current dust emission data from cattle feedlots in South Dakota that may be used in preparing zoning regulations. Regulators and others will be able to assist cattle feedlot producers on properly citing feeding facilities to minimize emissions. It is imperative that County Zoning Boards and Commissioners have scientific information to assess dust and PM potential from livestock operations to permit the expansion of the state's top economy.

Feedlot producers will benefit from the results of this research since odors can possibly be linked the amount of dust emissions. As an ever increasing study on limiting livestock odors, further researchers may use the data to create relationships between odor and PM levels.

Materials and Methods

The research was conducted during August 2006 on an 800+ head cattle feedlot located in eastern South Dakota. Three dust collection mechanisms were installed in the center of the feedlot to obtain levels of PM in the air via paper filters (Figure 1).

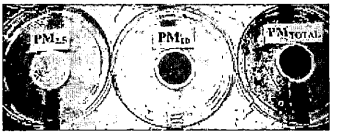

Figure 1. Sample picture of filters after testing.

The dust was collected at the $PM_{2.5}$, PM_{10} and PM_{Total} using Airmetrics model 4.2 air samplers (Figure 2).

Figure 2. Dust Collection Mechanism Used (Airmetrics model 4.2).

This instrument intermittently passes air at a known fixed flow rate through a paper filter to collect particulate matter. Grey particle size separators, as seen in Figure 2, mounted on top of the samplers limit PM particles of either $PM_{2.5}$ or PM_{10} from reaching the paper filter to obtain desired particle size. The instruments are equipped with run timers which allow for calculating the total volume of air sampled. The equation to determine total volume is explained below.

Volume m^3 = Flowrate (L/min) * (60 min/1 hour) * Time of Operation (hours)

The instruments were powered by rechargeable batteries which had a life of approximately six days. The paper filters were replaced along with a new battery every six days. Feedlot emissions were analyzed for a total of four consecutive sampling periods, each six days long.

The paper filters were weighed before and after sampling to obtain the mass of PM emissions collected during the sampling time. The filters and scale were contained in a humidity controlled environment to equilibrate before and after collection. The constant humidity level inside the chamber prevented distortions due to water weight from changes in humidity. The filters were weighed using a Sartorius model CP2P-F balance (Figure 3) that has accuracy to one microgram (0.000001g). The scale is placed on a large marble table to deaden or eliminate any vibrations that may distort the mass reading.

Figure 3. Sartorius scale used for weighing samples inside humidity controlled chamber.

The equation below explains how the mass of the PM collected was analyzed to produce a desired microgram (μg) value.

Mass (μg) = (M1 – M2)*1000

M1 = Mass of filter before sampling
M2 = Mass of filter after sampling
1000 = conversion factor (mg → μg)

Results and Discussion

Results from the four sampling periods are illustrated in charts directly comparing them with the national standards and also with other PM collection sites in the region. Figure 4 below displays the results of the $PM_{2.5}$ compared with the 15μg/m^3 standard.

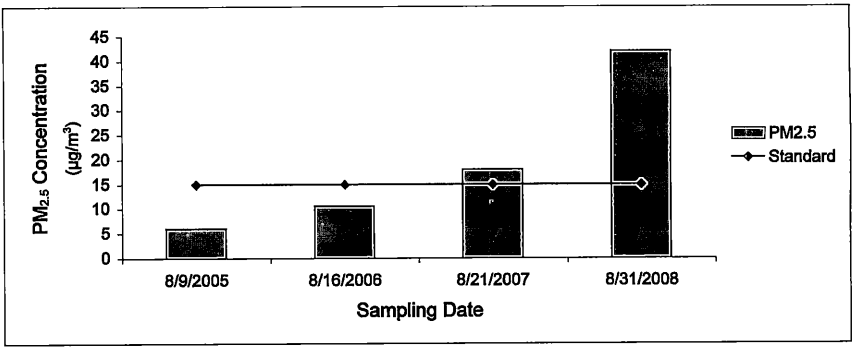

Figure 4. Experimental PM2.5 and Standard PM2.5.

Figure 4 shows a definite increase in emissions occurred over the four sampling periods. Ideally the experimental data should be lower than the standard line. The last collection of August 31, 2005 displays large amounts of $PM_{2.5}$ emissions. This exponential increase in production may be linked to various weather effects including: extreme temperatures, wind conditions, precipitation, and humidity. Weather data (Appendix A) from the region in the last week of August showed high average high temperatures (91.5°F), low relative humidity (46%) combined with moderate wind speeds (11.6 mph), all optimum conditions for dust production (Climate, 2005).

Figure 5 displays the results obtained from the PM_{10} emissions sampling.

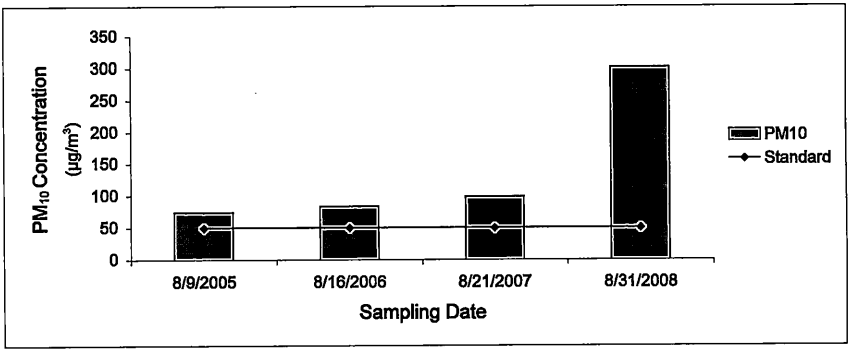

Figure 5. Experimental PM_{10} and Standard PM_{10}.

Figure 5 above examines the PM_{10} compared to the standard of 50 µg/m³. The same increasing trend as seen in $PM_{2.5}$ data in Figure 4 is seen in the PM_{10} emission data. These two charts are very similar, giving validity to each of the tests. The similarity in both charts reassures the data collected that the tests were accurate. This exponential increase towards the later dates is more than likely related to the optimum weather conditions as

explained before. It is very interesting to examine how the weather can play a major role in PM emissions.

A final stock chart (Figure 6) was created to give an average value of PM emissions with the ranges collected shown as high and lows for each PM size.

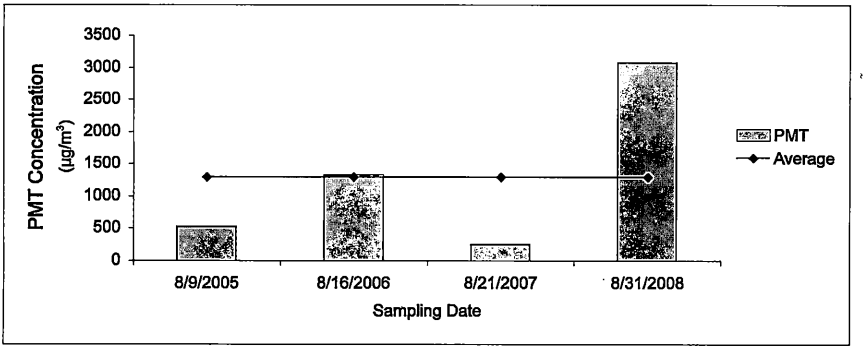

Figure 6. Stock Chart displaying high and lows along with the average emission for the month of August.

Total suspended PM (PM_{TSP}) was also monitored. The results shown in Figure 7 give an indication of how much large PM along with small PM were present in the air. Currently no standards exist on PM larger than 10 microns.

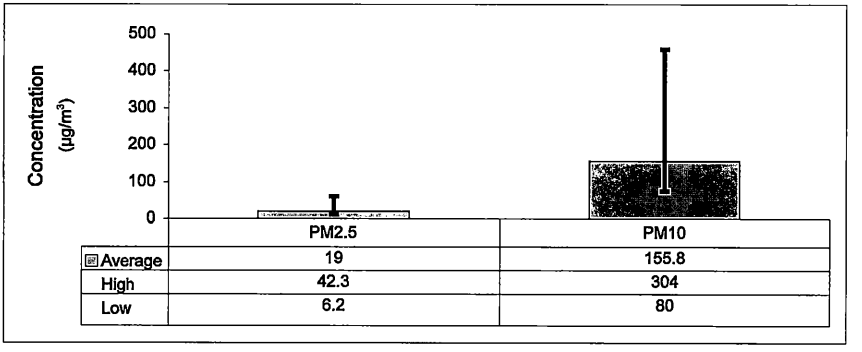

Figure 7. Experimental PM_{TSP} and Their Average.

PM emissions are monitored at various locations across the state. These stations are typically located in towns which are not directly exposed to PM emissions as this research project was. As a base to compare the experimental data found during the instruments, the two figures below give an idea of typical PM emissions data found in eastern South Dakota.

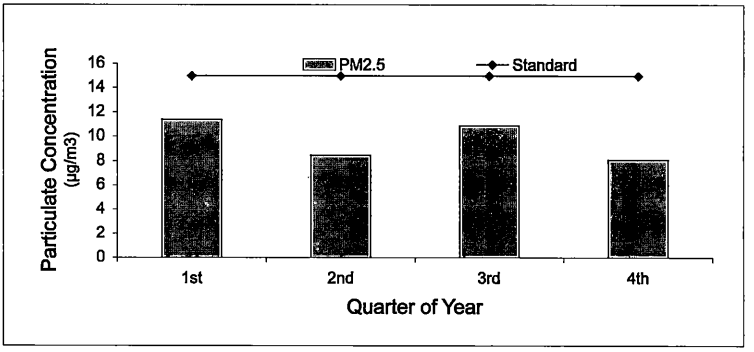

Figure 8. Experimental $PM_{2.5}$ and Standard $PM_{2.5}$ in the town of Brookings, SD. (Courtesy of SDDENR)

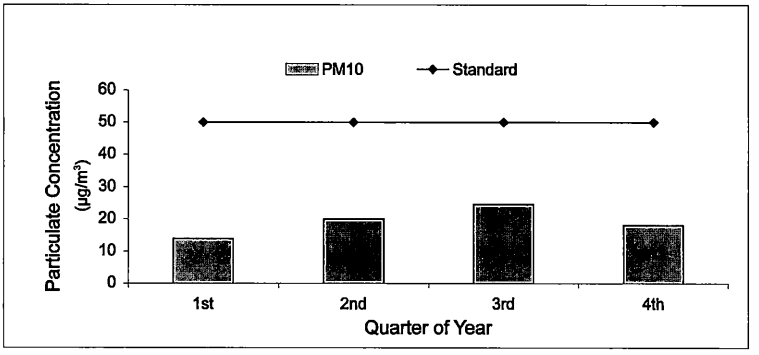

Figure 9. Experimental PM_{10} and Standard PM_{10} in the town of Brookings, SD. (Courtesy of SDDENR)

Figures 8 and 9 are comparable to the data collected at the feedlot. Obviously the emissions data for Brookings (pop. 17000) will be less than that of the feedlot. But in direct comparison of the $PM_{2.5}$ emissions, the feedlot produces only about twice as much $PM_{2.5}$ emissions as compared to typical air in Brookings, South Dakota. (19 $\mu g/m^3$ @ feedlot vs.10 $\mu g/m^3$ @ Brookings). The PM_{10} emissions are approximately eight times higher for the feedlot compared to that in Brookings. These two locations of study may have error in comparison due to different weather patterns because of the time when the samples were taken. Without other feedlot research to compare with, this provides a medium to compare to.

CONCLUSIONS

After completing this research, many conclusions can be made on the emissions from cattle feedlots. The sampling occurred during August (3rd Quarter) which typically results in the highest PM emission data, as seen in other reports. The increased PM emissions could be contributed to the weather. The weather can play a major role on PM emission. For example, during the last week of August, PM emissions were at their highest. This is related to the hot temperatures, dry soil conditions, low humidity, and the low wind conditions that occurred. Also, this summer was hot and dry which could have potentially favored PM emissions in August. The best possible solution to these certain weather circumstances would be to sample the feedlot for a period of three years. This would allow for extremes and would produce a more typical average value.

When comparing the feedlot results found in August to those in the city limits of Brookings, $PM_{2.5}$ and PM_{10} emissions from the feedlot were higher as expected, although the $PM_{2.5}$ emissions were not largely different. These are the emissions that the EPA is most sensitive about due to their health hazards. Since the feedlot's $PM_{2.5}$ emissions are slightly higher than the EPA standard for the worst possible conditions, it is apparent that cattle feedlots will not pose a health hazard and their averages would likely comply with the 15 $\mu g/m^3$ standard for $PM_{2.5}$ emissions. PM_{10} emissions seem to have more variability and response to weather compared to that of $PM_{2.5}$ emissions. More research is needed to accurately compare the PM_{10} emissions with the EPA standard of 50 $\mu g/m^3$.

FURTHER WORK

This research was conducted for only one month out of a year. To achieve the most accurate results a more in depth study should be conducted on a feedlot for a period of three years. This longer period will provide a better understanding and a concrete average value of PM emissions. Installation of a weather station should also be considered in continuation of this research.

REFERENCES

Enivronmental Protection Agency (EPA). 2003. National Air Quality and Emissions Trends Report. (Report Number EPA 454/R-03-005). Research Triangle Park, North Carolina: EPA.

Tomany, James P. 1975. Air Pollution: the emissions, the Regulations, and the Controls. 1st ed. New York, N.Y.: American Elsevier Publishing Company Inc.

Parker, Tim.2005. "The Economics of Food, Farming, Natural Resources, and Rural America.". Economic Research Service Online. Accessed March 20, 2006 <http://www.ers.usda.gov/statefacts/SD.htm#TCEC>.

"South Dakota Climate and Weather." SDSU Climate and Weather Online. 2005. Accessed March 10, 2006 <http://climate.sdstate.edu/climate_site/climate_page.htm>.

"Brookings Monitoring Site." Department of Environment and Natural Resources Online. 2005. Accessed March 14, 2006 <http://www.state.sd.us/denr/des/airquality/Monitoring/brookings.htm>.

VIBRATION ANALYSIS OF A BOAT AND DOCK

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Faculty Sponsor: Dr. Shanzhong (Shawn) Duan
Department: Mechanical Engineering

ABSTRACT

A structure is designed to withstand the maximum force that will be applied. In this case a boat dock is examined as a spring system. This exercise uses a typical design for a lake side boat dock, tires for buoys, and an average fishing boat. Vibration analysis can predict when the highest forces will occur. A solution can be found to graph the motion of the dock. In addition to the analytical solution, the MATLAB program is used to visualize the vibrations. With these tools the magnitude and timing of forces can be verified.

INTRODUCTION

To understand the forces on a dock when a boat hits it, it is possible to apply vibration analysis. If it is known how these forces act, better docks can be designed. Safety and strength can be improved by knowing the magnitude and timing of the force. Significant efforts have been put forward for vibration analysis of boats and docks by individuals whose interests lay in the various fields [1, 2, 3]. This paper goes through the process of vibration analysis and animation to discuss motion behaviors of the boat under the given initial conditions and its influence to the dock.

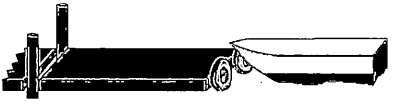

Figure 1. Real world system

Figure 1 is a simple drawing of a boat and a dock. The left side of the dock is a fixed section while the rest is an attached floating dock. In this real world situation there are forces, transitional and rotational, in all three dimensions. That makes a very complicated six degree of freedom system.

To focus on the spring motion of the dock the system is reduced to a one degree of freedom system.

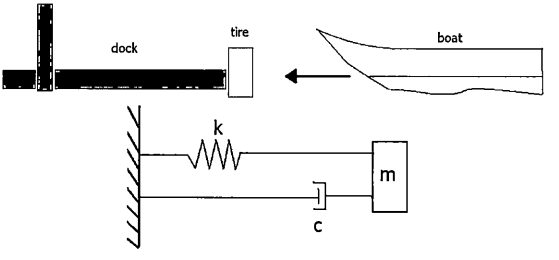

Figure 2. Reducing to a DOF system

The primary forces that will be analyzed act in a single direction, so the depth of the system can be ignored. Next the parts of the dock and boat system will be simplified into components of a Free Vibration Damped system: k-spring constant, c-damper, and m-mass.

The dock is made of wood that will absorb the impact of the boat and act as a spring for the system. A buoy, usually a tire or some rubber material, that protects the boat and dock from damage, plays the role of a damper. Water also acts as a damper on the boat as it approaches the dock. When the boat contacts the dock, it is assumed to be an elastic collision (boat and dock 'stick' together). This assumption means that none of the force is lost to the surroundings. In this way, the boat's mass is the mass of the system.

Other interactions, such as waves and currents, are considered negligible. This reaction is analyzed as a free vibration, where the initial velocity of the boat drives the motion. It is assumed that the boat is moving at a sufficiently slow speed and will not cause a forced vibration.

METHODS

From the diagram of the system as shown in figure 2., the equation of motion is set up based on Newton's second law of motion $\sum F = ma$ as follows:

$$m\ddot{x}(t) = -c\dot{x}(t) - kx(t) \qquad (1)$$

Manipulating equation (1), we have the following result

$$m\ddot{x}(t) + c\dot{x}(t) + kx(t) = 0 \qquad (2)$$

In equation (1) and (2), $\ddot{x}(t)$, $\dot{x}(t)$, and $x(t)$ are the acceleration, velocity, and displacement of the vibration system under consideration. t is time.

To find the solution, and to simulate and visualize the results using MATLAB program, three basic parts *m, c,* and *k* of the vibrating system must be determined. The mass of the system is the mass of the boat where m=500kg. The dock is formed by parallel wood beams. The axial directions of these beams are in the motion direction of the boat. Then the following equation is used for calculation of the spring constant k [4]

$$k = \frac{AE}{L} \qquad (3)$$

where A is cross-sectional area , E young's modulus, and L is the original length of wood beams. The area is 2.5m by 0.5 m, and the length is 10 m. There is a large range for the Young's Modulus of wood. These are highly dependent on the type and direction of the wood beams. Softer types of wood will adsorb more force. Since pine is both relatively soft and cheep it often used for docks. Its modulus is about 11GPa [5]. Calculating the spring constant from equation (3) will be:

$$k = \frac{(1.5m * 0.5m)11x10^9 \frac{N}{m^2}}{10m} = 825\frac{MN}{m}$$

This is a large spring constant but consistent for this system. The dock acts as a very stiff spring, deflecting only a small amount. Damping constant is the last to be found. Since it is known that a tire on a car will damp the vibration 233 N/(m/s). Tires in this system

do not have inner tubes deflecting in a horizontal direction. The damping constant is taken to be c=100N/(m/s) for this calculation.
Now that the constants are known, the system can be examined as a whole. The spring constant is very large and the damping force is small. After the initial deflection of the spring, the large spring constant will overcome the force. This allows a prediction of an under-damped system, as shown in figure 3.

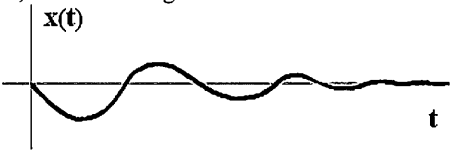

Figure 3: Sketch of the waveform

The graph tends toward zero due to the damping effect. However because the damping in this case is so small, the fluctuations will occur. After a short time the fluctuations will die out. It also should be noted that the graph is negative at the start. This shows that the initial reaction is to have a compressed spring.

To continue toward the solution of the system, the type of the system has to be mathematically determined. From definition of natural frequency and damping ratio, we have the following equations:

$$\omega_n = \sqrt{\frac{k}{m}}, \qquad (4)$$

and

$$\zeta = \frac{c}{c_c} \qquad (5)$$

where ω_n is natural frequency and ζ is damping ratio. In equation (5) the critical damping constant is c_c can be expressed as follows:

$$c_c = 2m\omega_n \qquad (6)$$

From equations (4), (5), and (6), numerical value of the damping ratio can be calculated as follows:

$$\zeta = \frac{c}{2m\sqrt{k/m}} = \frac{100}{2*500*\sqrt{\frac{825x10^6}{500}}} = 2.46x10^{-6}$$

The value of the damping ratio indicates that the system is an underdamped system.

Next the initial conditions will be applied to the system to obtaining the vibration response of the system. The initial conditions of the system are x_o=0 and $\dot{x}_0 = 5$ m/s. Since $\zeta < 1$, the vibration response of this system can be represented by the following equation:

$$x(t) = e^{-\zeta\omega_n t}\left(x_0 \cos\left(\sqrt{1-\zeta^2}\,\omega_n t\right) + \frac{\dot{x}_0 + \zeta\omega_n x_0}{\sqrt{1-\zeta^2}\,\omega_n} \sin\left(\sqrt{1-\zeta^2}\,\omega_n t\right)\right) \quad (7)$$

Substituting numerical values of each term into equation (7), the vibration response of the system can be represented by the following equation:

$$x(t) = -e^{-.00316t}\left(0.0389\sin(1284.5t)\right) \quad (8)$$

Next MATLAB software will be utilized to verify the mathematical derivation and dynamical analysis we had above. MATLAB [7] is a software package from MathWorks. With basic coding, it is possible to graph and animate a equation in MATLAB. The file extension is ".m" and is only used by MATLAB.

Two programs that were written by Dr. Nordenholz [6] have been used to make animation. They are as follows:

```
function freesmd_sim(t,x)
%Animation function for a horizontal spring/mass/damper
%Written by T. Nordenholz, Fall 05
%To use, type free_sim(t,x) where t and x are the time (sec) and
%displacement (m) arrays
%Geometrical and plotting parameters can be set within this program
% set geometric parameters
W=.05; %width of mass
H=.1; %height of mass
L0=1;%unstretched spring length
Wsd=.5*H; %spring width
xrect=[-W/2,-W/2,W/2,W/2,-W/2]; % plotting coordinates of mass
yrect=[0,H,H,0,0];
%set up and initialize plots
%x vs t plot
Hf=figure('Units','normalized','Position',[.1,.1,.8,.8]);
Ha_f2a1=subplot(2,1,1);
Hls_f2plot1=plot(t(1),x(1));axis([0,t(end),-L0,L0]),grid on,...
 xlabel('t (sec)'),ylabel('x (m)')
% animation plot
Ha_f2a2=subplot(2,1,2);
% create mass
Hp_f2rect=fill(xrect+x(1),yrect,'b');axis([-L0,.5,-H,2*H]),grid on
Hl_cm=line(x(1),H/2,'Marker','O','MarkerSize',8,'MarkerFaceColor','k');
% create spring/damper
Hgt_springdamp=hgtransform;
Hl_Lend=line([0,.1],[0,0],'Color','k','Parent',Hgt_springdamp);
Hl_Rend=line([.9,1],[0,0],'Color','k','Parent',Hgt_springdamp);
Hl_Lbar=line([.1,.1],Wsd*[-1,1],'Color','k','Parent',Hgt_springdamp);
Hl_Rbar=line([.9,.9],Wsd*[-1,1],'Color','k','Parent',Hgt_springdamp);
```

```
Hl_spring=line(linspace(.1,.9,9),Wsd*[1,2,1,0,1,2,1,0,1],'Color','k','Parent',Hgt_springd
amp);
Hl_dampL=line([.1,.4],Wsd*[-1,-1],'Color','k','Parent',Hgt_springdamp);
Hl_dampLpist=line([.4,.4],Wsd*[-1.3,-.7],'Color','k','Parent',Hgt_springdamp);
Hl_dampR=line([.6,.9],Wsd*[-1,-1],'Color','k','Parent',Hgt_springdamp);
Hl_dampRcyl=line([.55,.6,.6,.55],Wsd*[-.5,-.5,-1.5,-
1.5],'Color','k','Parent',Hgt_springdamp);
% set initial length
L=L0+x(1)-W/2;
set(Hgt_springdamp,'Matrix',[L,0,0,-L0;0,1,0,H/2;0,0,1,0;0,0,0,1]);
text(0,1.5*H,'|-> x');
% draw and hold for 1 second
drawnow
tic;while toc<1,end
tic

% Animate by looping through time and x arrays
% and redrawing at each value
for n=1:length(t)
 L=L0+x(n)-W/2;
 set(Hls_f2plot1,'XData',t(1:n),'YData',x(1:n));
 set(Hp_f2rect,'XData',xrect+x(n));
 set(Hl_cm,'XData',x(n));
 set(Hgt_springdamp,'Matrix',[L,0,0,-L0;0,1,0,H/2;0,0,1,0;0,0,0,1]);
 while toc<t(n),end;
 drawnow;
end
```

The next program is called Freevib.m and is written as follows:

```
%free spring/mass/damper
clear,clc,close all
%set parameters
%all dimensions in m, kg, s
k=825*1066;m=500;c=100;
x0=0;v0=5;
%calculate Wn(natural frequency) and z(damping ratio)
Wn=sqrt(k/m);
z=c/2/sqrt(k*m);
%define time array
t=0:.02:5;
%generate x array (depends on z)
if z<1
 %underdamped case
 Wd=Wn*sqrt(1-z^2);
 A=sqrt(x0^2+((v0+z*Wn*x0)/Wd)^2);
```

```
 phi=atan2(x0,(v0+z*Wn*x0)/Wd);
 x=A*exp(-z*Wn*t).*sin(Wd*t+phi);
else
     x=0
end
%plot and animate
freesmd_sim(t,x);
```

The first highlighted section sets up the constants that have already been determined. For this case it is already known that our system is an underdamped case. If the program finds this to be true it will graph the solution. Other wise it will return a x=0. Other programs can be written for critically damped or overdamped systems.

RESULTS

Figure 4 is the resultant graph produced by two MATLAB programs. The lower section of figure 4 oscillates with the graph to show the range of motion. These results illustrate with what is known and assumed about the system.

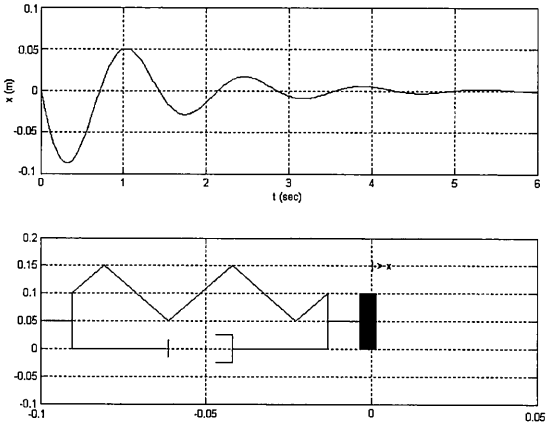

Figure 4. MATLAAB results

The damping is small creating an underdamped system. The boat impacts the dock, creating a compression in the system. The wood makes a very stiff spring, so its deflection is small. That deflection quickly tends goes to zero.

Now that this work is completed, the effect this has on design can be examined. The initial force and deflection is the largest in the reactions of the spring. So when designing a dock these are the forces that should be analyzed for strength based design. The motion and vibrations can be further used in fatigue based design.

LIMITATIONS

This paper is a preliminary theoretical derivation and analysis. It could be improved through a forced vibration analysis, accounting for more degrees of freedom, and performing experiments on actual docks. This project could also be extended to include larger ships, forces, etc. This author intends to apply what has been learned to a specific problem in practice and provide preliminary results for further analysis and research.

REFERENCES

[1] Narurkar, P. H.; Singh, O. "Design Of A Dry Dock." Journal of the Institution of Engineers (India), Part CV: Civil Engineering Division. Vol 56. July, 1975. pp. 17-22.

[2] Juodeikiene, I. and Norvvdas, V. "Compression Strength Of Oak And Ash Wood Perpendicular To Grain." Materials Science. Vol. 11 No. 1. 2005. pp. 40-44.

[3] Shelden, J. G. "Application of a Structural Analysis Program to Floating Dock and Guide Pile Design." Proceedings of the First International Conference on World Marina. 1991. pp. 226-235.

[4] Rao, S. S. Mechanical Vibrations. 2004. New Jersey: Prentice-Hall.

[5] eFunda. Properties of Common Solid Materials. http://www.efunda.com/ Copyright © 2007 eFunda

[6] Nordenholz, T. "Animation as the Final Step in the Dynamics Experience." Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition. Chicago,IL. 2006

http://www.mathworks.com/matlabcentral/fileexchange/loadFile.do?objectId=11258

[7] MATLAB © The MathWorks, Inc.

Assessment of Biosecurity Procedures to Prevent Bovine Viral Diarrhea Virus Cross Contamination

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Faculty Advisors: Dr. Chris Chase, Lyle Braun
Department: Veterinary Science

ABSTRACT

Bovine viral diarrhea virus (BVDV) is a common virus among cattle, and there are many different strains of the virus. BVDV can cause mucosal disease in infected cattle. There are lab strains of BVDV used for testing, but there are also wild-type viruses that may develop within a herd or population. These wild-type strains can be dangerous due to cross contamination between herds. This project compares serum samples from two different herds on the basis of the antibody response to a wild-type virus isolated from a persistent infected animal in one of the herds. We tested for a possible cross contamination between a persistently infected herd and a non-persistently infected herd. Cross contamination can cause errors in data collected from the non-persistently infected herd. Serum neutralization testing was done to measure a response to a specific virus strain. Our results indicated that there was no cross contamination.

INTRODUCTION

The BVDV virus was first isolated in 1946 when it was causing depression and diarrhea in infected cattle. Some years later, in 1953, another virus named Mucosal Disease Virus was isolated that caused erosive lesions in the digestive tract of infected cattle. Soon after, due to serological testing, the two viruses were found to be the same virus.

Bovine viral diarrhea (BVDV) causes a number of diseases in cattle. It is a ss RNA virus of the genus Pestivirus and family Flaviviridae. The effects are dependent on strain, age of cattle, and immunity of herd. There are many strains consisting of cytopathic and non-cytopathic strains. It is found in low levels in most cattle development operations. Transmission typically occurs through horizontal transmission within the herd by either inhalation or contact with body fluids. Fomites, while rare, may also transmit the virus. BVDV is most serious when it infects pregnant cows. The BVDV virus can lead to abortions, premature births, or stunted calves at birth. BVDV may be present in a cow and not cause visible disease, while at other times it can cause serious diarrhea along with oral sores. The non-disease causing virus may still weaken the immune system, creating an opportunity for other infections.

Persistent infection can occur in a herd. These herds constantly have virus in their cells and constantly shed virus but disease may appear and reappear periodically. Persistence is caused when a pregnant cow becomes infected with BVDV, and the virus crosses the placenta, infects the calf, and the calf is born infected with the BVDV virus. This calf remains permanently infected and constantly shedding virus.

Many procedures go into testing serum samples for antibodies against a strain of BVDV. Virus production is performed to grow virus stock to perform additional tests. Cells are infected with the virus and virus particles are harvested from the solution. A tissue culture infectious dose 50 (TCID 50) is performed to test for the titer of the virus. Finally, serum neutralization is performed with serum samples. A serum neutralization test is used to test many samples for antibodies against a certain virus strain. Information on BVDV can be gained on many herds by using serum neutralization tests. Also if a cow does have antibodies against a virus, a titer, which is a measure of antibody level, can be obtained from the serum neutralization tests.

The objective of this study was to test two different herds for cross contamination with a virus and by testing the antibody titer of the cattle that may have been cross contaminated.

MATERIALS AND METHODS

Three BVDV strains, type 1a Singer, type 2a A125 and a wild type 2a SD05-13414 were used. To start the study, virus was added to bovine turbinate (Bt) cells to produce virus for the study. The virus-infected solutions were then frozen and thawed multiple times; the virus supernatant was collected, placed into cryovial tubes, and frozen at -80C. Cell culture was performed to harvest Bt cells to run a TCID 50 assay. A TCID 50 was performed by placing growth media and two-fold virus stock dilutions down a row in a 12-well plate. Cells were then added to each well, incubated, and observed for cytopathic effects (CPE) after a few days. The plate was read to determine the highest dilution where the virus produced CPE, and the TCID 50 value was calculated. Finally, a serum neutralization was prepared with the virus that showed the most obvious CPE and the highest TCID 50 value. Each well was innoculated with 300 TCID 50. Growth media (minimal essential media and antibiotics), test serum, and virus stock working solution were added to each well of a 96-well plate and incubated. A backtitration was also performed in one of the plates to demonstrate how much virus was present to be neutralizedd by the test serum. Susceptible Bt cells were then added to the wells and incubated again for 5-7 days. The serum neutralization plate was then read for the presence of CPE to determine which, if any, serums contain antibodies against the virus. If antibodies were present, the titer of the antibody was calculated as well.

RESULTS

The presence of antibodyand titer was achieved by running the serum neutralization assay. Results for both the SDSU PI herd and the SDSU non-PI herd were compared.

Columns 1 and 2 compared BVDV type 1 and BVDV type 2 antibody titers of the calves against the three test strains. The wild-type BVDV virus 05-13414 was the cytopathic virus isolated from PI 44 and was the virus tested for cross contamination into the non-PI herd.

Calves PI 31, PI 36, PI 41 and PI 44 developed antibody titers to the wild-type virus in the PI herd. This was expected since these animals were in the PI herd. The non-PI herd was negative for antibodies against the wild-type virus. This data indicated that no cross contamination occurred between the SDSU non-PI herd and the SDSU PI herd.

DISCUSSION/CONCLUSION

The purpose of this study was to test two herds for cross contamination with a wild-type virus. The two herds were less than 100 yards apart and were fed and cared for by the same personnel. Prior to bringing the non-PI herd to the facility, strict biosecurity measures were implemented to prevent cross contamination. The data indicated that there was no cross contamination between the two herds. The SDSU non-PI herd showed no antibody titer for the wild-type virus isolated from the SDSU PI herd. Even though cross contamination is very possible between herds, the implementation of biosecurity procedures can effectively prevent cross contamination.

ACKNOWLEDGEMENTS

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REFERENCES

Albrecht, Thomas, Istvan Boldogh, and David D. Porter. Persistent Viral Infections. April 30, 2007. http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=mmed.chapter.2431

Kirkpatrick, John G. DVM. Persistent Bovine Virus Diarrhea Infection in Cattle. April 30, 2007. http://64.233.167.104/search?q=cache:6fGgkzGW0yUJ:www.ansi.okstate.edu/exten/cc-corner/archbvdv.html+%22persistent+infection%22&hl=en&ct=clnk&cd=6&gl=us

Tremblay, Robert. Bovine Viral Diarrhea. April 30, 2007. http://www.omafra.gov.on.ca/english/livestock/dairy/facts/bovinevi.htm

American Indian Transportation Issues in South Dakota

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ABSTRACT

This paper provides an overview of tribal transportation obstacles. My primary focus is on the quality of reservation roads and its relationship to funding and politics. The Indian reservation road system is one of the most underdeveloped transportation networks in the United States. A majority of these roads are dirt and gravel and, therefore, dangerous for traveling. Motor vehicle accidents are the leading cause of death for American Indians and Alaska Natives between ages one and 44 (Hamilton 2003). Because federal funds for tribal transportation fall short of transportation needs, tribes do not have enough money for either road construction materials or road repair and maintenance. As a result, reservation roads are undeveloped and have come under a state of disrepair.

Tribal politics are of particular importance in reference to road management. Tribal officials rarely serve terms longer than two or three years. Few officials are reelected and brief terms make efficient management difficult. Compounding the issue is an overall lack of communication between tribal officials and between state, federal, and tribal transportation departments. In addition, one interviewee states "Families control tribal government" (BIA Highway Engineer). While the needs of the families in governmental positions come first, the needs of tribal members come second. In addition, a BIA employee reports mismanagement of funds, incomplete financial records, corrupt government, and more.

The list of tribal transportation problems is a lengthy one, but the list of solutions is brief. Suggested improvements include an open line of communication, hiring and maintaining competent tribal employees, and increased funds. Further research needs to be conducted in this area to investigate effective transportation models. Furthermore, transportation problems negatively affect American Indian employment, health, and education. Little has been researched in this area, and a further investigation needs to be conducted to determine how these areas are affected.

INTRODUCTION

I've spent three summers working for an engineering consultant firm running laboratory tests on road materials to assure quality. Some of this work was on reservations in South Dakota. A couple years ago I got into a car accident on a reservation road. The project I was on was supposed to be done four years ago. The road was graded

and the base course was laid when the project ran out of money. The unpaved road sat there for two years, untouched. When enough funds were gathered to pave the road, there wasn't enough money to also re-grade it too. Some water was sprayed over the dirt and gravel, base course was laid, and the paving began. That's about the time I was scheduled to work in the lab on this project. I was driving below the speed limit when I fish-tailed, lost control, and rolled several times into the ditch. I was lucky to live, but many others are not as fortunate.

METHODS

The bulk of this research consisted of a analysis of existing data reports from the public files of the U.S. Department of Transportation. In addition, brief topical interviews with individuals who have experience working with transportation issues on U.S. reservations were conducted for place-based information.

THE TRANSPORTATION CRISIS

The transportation needs of American Indians in South Dakota are similar to the needs of all people living in rural areas. Many American Indian tribes live in "isolated locations with little arable land and few natural resources" (USDOT 2001). There is no local transit system and many people lack adequate transportation. Due to this, some medical and food services are delivered to individuals in their homes and hitchhiking is common. In cases of severe weather, many homes on reservations are inaccessible (Shawn 2006).

Lack of adequate transportation perpetuates isolation, and "...reservations are among the most economically depressed areas of the country with very high unemployment rates" (USDOT 2001). A survey was conducted by the Center for Urban and Regional Affairs at the University of Minnesota of more than 1,200 households in the early 1990s. Seven American Indian sites located in North Dakota, Wyoming, Minnesota, Utah, and Colorado were included. This study found that:

- 25% of respondents indicated they had lost a job because of a transportation problem,
- 36% said they had turned down a job because of a transportation problem,
- 29% said a health crisis requiring medical attention created a transportation problem,
- 27% indicated that they lost an opportunity for education because of a transportation problem (Shawn 2006).

Indian Law

The Tribes of the Great Sioux Nation signed treaties with the Unites States in the 1800's which established the territorial boundaries of the tribe and recognized the rights of the Sioux as a sovereign government. In exchange for land cessions, the United States promised to provide transportation within Indian lands. In other words, "the Federal Government is responsible for providing access within Federal and Indian lands"

(Hamilton 2003). As a sovereign government, the Sioux Nation has the power to govern both its land and its people. The Bureau of Indian Affairs (BIA) is the branch of the federal government which oversees transportation on Indian lands.

An Overview of Indian Reservation Roads

Native American communities depend on the Indian Reservation Road (IRR) system to "provide access to and within Indian reservations, Indian trust land, restricted Indian land, eligible Indian communities, and Alaska Native villages. More than 2 billion vehicle miles are traveled annually on the IRR system," (Hamilton 2003).

There are two classifications of Indian Reservation Roads: Bureau of Indian Affairs (BIA) system roads and state/county/local roads. BIA roads are owned and maintained by the BIA and tribal governments. State roads are owned and maintained by the state, the county is responsible for county roads, and the township is responsible for local roads.

Federal Funding

The federal agency responsible for transportation is the Federal Highway Administration (FHWA). The FHWA provides access within Indian lands by funding the Indian Reservation Road (IRR) system. Public Law 93-638 is used to administer FHWA funds directly from the BIA to the tribe for transportation plans and construction. In comparison, state projects are also funded through the FHWA, and the money is generated through the state and federal fuel tax.

Prior to the 1980s, federal funding for transportation had to compete with non-transportation needs. The unpredictability of these appropriations "caused many road systems on Federal lands to fall into a state of dilapidation" (Hamilton 2003). The 1982 Surface Transportation Assistance Act (STAA) established the Federal Lands Highway Program (FLHP). The STAA sets funding aside specifically for transportation needs. The FLHP is a transportation program funded through the Highway Trust Fund. "The FLHP funds may be used for transportation planning, research engineering, and construction" (Hamilton 2003). Funding is determined through an Indian Reservation Road inventory and by setting a road project priority list to determine the amount of money needed to meet transportation needs.

Road Quality

The IRR system is among the most underdeveloped transportation networks in the United States. "Over 66 percent of the system is unimproved earth and gravel and approximately 24 percent of the IRR bridges are classified as deficient (functionally obsolete and/or structurally deficient)" (Hamilton 2003). The quality of a road affects safety, and the IRR roads are among the most dangerous roads traveled. "The annual fatality rate on Indian reservation roads is more than four times the national average" (Hamilton 2003). High road fatality rates on reservation roads are a reflection of the poor quality of these roads. In addition, "motor vehicle fatality rates are nearly 75 percent higher for Indians and Alaska Natives as for non-Indians." In fact, "motor vehicle injuries are the leading cause of death for American Indians and Alaska Natives between the ages of one through 44" (Hamilton 2003).

As seen in the chart below, the fatality rate of motor vehicle crashes is considerably higher on reservations than other areas. In fact, "5,962 fatal motor vehicle crashes occurred on roads under the jurisdiction of Indian reservations between 1975 and 2002, an average of 213 fatal crashes per year" (USDOT NHTSA 2004).

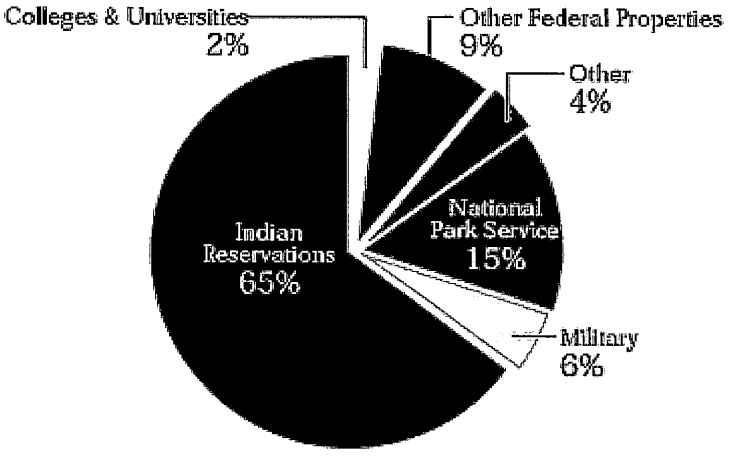

Figure 1. Fatal Motor Vehicle Crashes on Indian Reservations: 1975-2002. Source: U.S. Department of Transportation, National Highway Traffic Safety Administration, and the National Center for Statistics and Analysis (2004).

The number of fatal motor vehicle crashes per year increased 52.5 percent on reservations from 1975 to 2002. "While the number of fatal crashes in the nation declined 2.2 percent" (USDOT NHTSA 2004).

To illustrate the severity of the problem poor road quality can have on safety, Vic Glover, a former journalist and professor of communication and local resident of the Pine Ridge Reservation, writes:

> "Slim Buttes Road runs north to south for thirty-two miles, connecting Highway 18, which runs past Oglala, to Highway 20, running through Chadron. The upper part of the road is partially paved to the reservation line, then it turns to gravel for the last twenty miles to Chadron... Simply put, Slim Buttes Road is a killer... For as much traffic as there is on it, day or night, it's got to be one of the deadliest and worst high-volume roadways in the nation. As a rule, reservation roads are notoriously bad, but this one is in a class all by itself. If Indians had a wish list, there would probably be a lot of other items at the top, but something you hear the locals say quite often is, 'I sure wish they'd fix that road' (2004)."

DISCUSSION

In an interview with a BIA Highway Engineer, tribal transportation funding was linked to deficiencies in the quality of Indian Reservation Roads. He states:

> "Tribes do not get enough money to cover all their expenses. There are very few maintenance dollars. Without maintenance, roads dilapidate faster and require more maintenance or replacement, but there is not enough money to rebuild the road. Often times, a contractor doesn't follow the specifications and the tribe doesn't enforce the specifications. The quality of the road is compromised, and the road requires more maintenance due to poor quality. The road doesn't get maintained because of the lack of funds, and the life of the road is shortened."

BIA transportation funding affects the quality of Indian Reservation Roads. A manager at an engineering consultant firm explains,

> "... sometimes these funds are not enough to cover the entire cost of the project and construction is postponed until the following year. This can lead to a decrease in quality. For example, if the base course of a road is laid but isn't covered until the following year, the base course will lose compaction and may require re-grading. Once funding needs are met to lay the asphalt, additional funding is required to re-grade the road. Due to the delay in the asphalt surfacing of the project, project costs increase, and the project work is adjusted to fit the available funds. In other words, the road may not be re-graded and the longevity of the road is compromised."

The Safe, Accountable , Flexible, and Efficient, Transportation Equity Act of 2003 (SAFETEA) attempts to address the "very serious problem" of poor road quality on Indian reservations "by authorizing nearly $2 billion in funding for the IRR program for fiscal years (FY) 2004 through 2009... SAFETEA more than doubles the amount of funding for highway safety" (Hamilton 2003).

However, the SAFETEA Act may create additional financial barriers as well. Prior to the passage of this act, the BIA was allowed to shuffle funds between tribes on the basis of transportation needs. This policy changed with the passage of SAFETEA. An Engineer with experience working with Indian tribes explains:

> "Under this act, tribes have to ask permission from other tribes to use unutilized funds. It is an opportunity to create tension between tribes... Tribes compete for these funds and so they are at odds with each other. No tribe is happy with what they get."

Tribal Politics

Tribal politics also influence quality and efficiency of tribal transportation systems. A Highway Engineer for the BIA claims,

> "Families control tribal government... The families of the individuals elected into tribal government have first priority. Everyone else's needs are second place." He went on to say, "Financial records are incomplete, funds are mismanaged, there is corruption in tribal government, and the accounting system is lax at best at the tribal level. There is also a lack of continuity in tribal government due to brief office terms. Every two to three years tribal officials are elected out of office and someone new takes over with few exceptions. Very few people are reelected. Brief terms prohibit consistency and efficient management."

Solutions

The suggestions for improving quality and efficiency of tribal transportation are brief. One area needing improvement is communication. A seasoned Engineer explains:

> "There is an overall lack of communication. Working relations could be improved with more communication and better communication. I don't know how you fix that. A lot of people on the reservation run on Indian time, meaning that calls aren't returned in a timely fashion. This is sometimes unavoidable."

A more open line of communication would help. An open line of communication involves more information going out of progress, problems, and issues regarding scheduling and quality. Keep the tribal community informed of the work being done and future plans. Also, input and feedback from the tribal community regarding their concerns and their priorities would facilitate their involvement in transportation projects. Providing contact information to keep the community up-to-date with projects and plans provides an understanding of the process involved. An overall better understanding of both the state operations and educating the state of tribal culture helps alleviate misunderstandings.

Along with communication, government employment is another area needing improvement. A BIA Highway Engineer suggests, "Hire and maintain competent people in tribal government who receive adequate training." But it is not that simple. The problem in hiring and maintaining a skilled workforce has its roots in tribal politics. He explains,

> "Tribal government tends to do whatever they want to do or do what the person with the most clout in the neighborhood wants them to do... It is difficult to find good, qualified people. Competent employees sometimes get fired for doing their job. Local people are hired regardless of skill level. Often times these employees are not trained to do their job correctly."

To fix the problem, the organization of Tribal Government would have to change to allow tribal members to have more power regardless of family or political ties. All governments have their faults. The battle over power and influence is perpetual and is an issue that tribal governments face; it is an issue all governments face.

CONCLUSION

The list of problems affecting transportation on South Dakota's reservations is a lengthy and complicated one: geographical isolation, no public transit, poor road quality, inadequate funding, tribal politics, lack of skilled and competent tribal government employees, inadequate training, lack of communication, and tribal employees running on 'Indian time.' It seems there are no clear answers to complex issues. State employees working on reservation roads are required to attend courses informing them of tribal culture. It is a new program which may yield some improvement in communication between state and tribal highway workers. However, its progress cannot be measured at this time.

Further research is needed in regard to the relationship of the Sioux to the state of South Dakota regarding transportation issues. Case studies of the various reservations may be beneficial to understanding the variances and complexity of transportation issues. Effective transportation management models may be found through an analysis of additional American Indian tribal transportation models. Improvements may be made by utilizing working models other tribes have found to be successful.

REFERENCES

BIA Highway Engineer. August11, 2006. Personal interview.

Glover, Vic. 2004. Keeping Heart on Pine Ridge: family ties, warrior culture, commodity foods, rez dogs, and the sacred. Summertown: Native Voices.

Hamilton, Arthur. 2003. United States Senate Hearing on Proposals to Amend the Indian Reservation Roads Program -S. 281, The Indian Tribal Transportation Improvement Act of 2003 and S. 725, The Tribal Transportation Program Improvement Act of 2003.

Engineer. July 15, 2006 Personal interview.

Manager. August 1, 2006. Personal interview.

Shawn, Kelly. 2006. "American Indian Transportation: Issues and Successful Models." Retrieved June 27, 2006. http://www.ctaa.org/ntrc/rtap/pubs/ta/am-ind.asp.

USDOT. 2001. Conditions and Performance of Transportation Serving Federal and Indian Lands. US Department of transportation Federal Highway Administration.

USDOT NHTSA. "Fatal Motor Vehicle Crashes on Indian Reservations 1975-2002." National Center for Statistics and Analysis. Apr. 2004. 17 June. 2006. http://www.ncai.org/ncai/advocacy/cd/docs/transportation-fatal_crashes.pdf.

Effects of Letter Transposition in Subliminal Primes on Perceived Content of Abstract Images

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ABSTRACT

Subliminal presentation of a stimulus can influence responses to later stimuli. This effect is known as priming. The current study used Microsoft PowerPoint as a novel, low-cost paradigm to present experimental stimuli. Thirty-one undergraduate participants viewed a PowerPoint presentation that contained conditions with no, with unscrambled, and with center-scrambled sexually-themed messages. The effects of gender, counterbalancing, and type of message on perceived sexual content in experimenter-made inkblots was assessed. The current study failed to find any significant differences or interaction effects between any of the variables. A post-hoc analysis revealed a significant priming effect. Possible confounding variables and suggestions for future research are discussed.

INTRODUCTION

Subliminal presentation of a stimulus has been shown to influence responses to later stimuli (Ferguson, Bargh, & Nayak, 2005). This effect is known as priming with the preceding stimulus known as a prime. Masking and short stimulus duration are used to render primes unidentifiable ("subliminal"). Even under these circumstances, however, a stimulus used as a prime is capable of priming a response to the target stimulus for a minimum of 1 second following the onset of the prime (Visser, Merikle, & Di Lollo, 2005).

Semantic priming studies use primed words to affect participants' later interpretation of other words (Abrams, 2005; Abrams & Greenwald, 2000; Abrams, Klinger, & Greenwald, 2002; Draine & Greenwald, 1998; Greenwald, Draine, & Abrams, 1996; Kouider & Dupoux, 2004). Evaluative priming studies can use a variety of stimuli as primes and rely on participants' automatic interpretation of the primed stimulus as "good" or "bad" to influence their reactions to later stimuli (Duckworth, Bargh, Garcia, & Chaiken, 2002; Ferguson et al., 2005; Klauer, Roßnagel, & Musch, 1997). Affective priming studies use emotionally laden stimuli as primes to affect participants' responses to later target stimuli (Hermans, Spruyt, De Houwer, & Eelen, 2003; Klauer, Mierke, & Musch, 2003).

Most priming studies use one consistent type of stimulus for both the prime and the target stimuli (i.e., one picture as a prime followed by another as the target stimulus). In

contrast, and in line with the current study, Spruyt, Hermans, De Houwer, and Eelen (2002) used word primes and picture targets as a condition in their Experiment 3. Unfortunately, they found only a marginally significant priming effect ($p = 0.079$). They claimed this result was because semantic processing of pictures is more effective than semantic processing of words, so pictures therefore serve both as better primes and as better target stimuli than do words.

The features of the stimuli used are known to affect priming effects. Processing of the masks can interfere with processing of the relevant stimuli (Ja kowski & Przekoracka-Krawczyk, 2005). Additionally, Storbeck and Robinson (2004) found that words used as primes need to be semantically related in order for priming to occur and Thomas and LaBar (2005) found greater priming effects when using "taboo" words rather than neutral words.

Another dimension that could be important with respect to using a word as the prime is the physical features of the word itself. Abrams (2005) found that subliminal processing occurred not for the whole word, but at four- to five-letter parts of words. Researchers have found that reading speed is slower for words with an altered shape (Rayner & Kaiser, 1975) and for words with the center letters scrambled (Rayner, White, Johnson, & Liversedge, 2006). According to Grainger and Whitney (2004), when some of the letters in the target word are deleted, the resulting word functions as a prime only when the letters are in order ("relative position priming," p. 58). Moreover, when all the letters are present, the letters can be jumbled and the resulting jumbled word will still function as a prime ("transposition priming," p. 58). In contrast, Perea and Lupker (2004) found that words with transposed letters functioned as primes only when the transposed letters were consonants as opposed to vowels. Furthermore, Christianson, Johnson, and Rayner (2005) found significant priming effects only when letter transpositions occurred within morphemes rather than across them.

In the current study, both unscrambled and center-scrambled sexual words, similar to the ones used by Thomas and LaBar (2005), will be used as primes. Experimenter-made inkblots will serve as target stimuli. Processing of center-scrambled words takes longer than processing of unscrambled words, possibly due to a lack of practice reading center-scrambled words. Therefore, center-scrambled words should not function as effectively as primes as will unscrambled words, hence more inkblots with unscrambled-word primes should be described sexually than will inkblots with center-scrambled primes or with no primes. Additionally, in order to highlight variables for future research, the effects of gender and of counterbalancing order will be assessed to determine if either affects the degree of sexual content participants perceive in inkblots.

METHOD

Participants

Thirty-one undergraduates (6 men and 25 women) recruited from psychology classes at South Dakota State University participated. The participants ranged from 18 to 22 years of age, with a mean age of 20.19 years ($SD = 1.33$ years). The group of

participants represented all undergraduate educational levels (n = 6 freshmen, n = 8 sophomores, n = 11 juniors, n = 6 seniors). The students received extra credit for their participation. All researchers involved in this study followed APA ethical guidelines (American Psychological Association [APA], 2002) and completed NIH online training on protection of human participants (http://cme.cancer.gov/clinicaltrials/learning/humanparticipant-protections.asp). The Institutional Review Board at South Dakota State University approved this project.

Materials

Sexual words, both taken from and modeled after those used by Thomas and LaBar (2005), were used as primes. The specific words used can be seen in Table 1. The chosen words were center-scrambled without respect to either morphemes or whether the letters were consonants or vowels. Experimenter-made inkblots were used as target stimuli. Participants circled on a data-recording sheet whether what they saw in the inkblot was violent, happy, human, drug-related, sad, angry, animal, or sexual in nature. These categories were staggered within each response to avoid biasing the participants' interpretations.

Procedure

Before participants were recruited, students in the upper level Experiments in Psychology class at South Dakota State University evaluated 20 inkblots rotated three different ways and 34 words for perceived sexual content on a 1-9 scale. The mean rating of sexual content in all inkblot orientations was assessed, and the ten blots with z-scores in the medium range of ratings were chosen for the study (chosen range: -0.28 to 0.30). The ratings of all participants for each word were averaged, and the ten words they rated as most graphic in terms of absolute ratings (range: 5.90 to 6.60) were chosen for the study.

Participants initially recruited for the study were told they would assess individual differences in the interpretation of abstract images. It was necessary to explain the project broadly, because if participants had known they would be viewing subliminal messages, they might have changed their behavior with respect to describing the inkblot content. Participants were fully debriefed following the experiment.

Table 1.

Words Used as Priming Stimuli

Unscrambled	Center-Scrambled
vagina	vniaga
clitoris	cioitlrs
orgasm*	oasgrm
masturbation	mubosatriatn
vibrator	vbatoirr
dildo*	dldio
ejaculate*	eltucjaae
incest*	iescnt
pussy*	pssuy
schlong*	snlchog

Note. An asterisk denotes words from Thomas and LaBar's (2005) study.

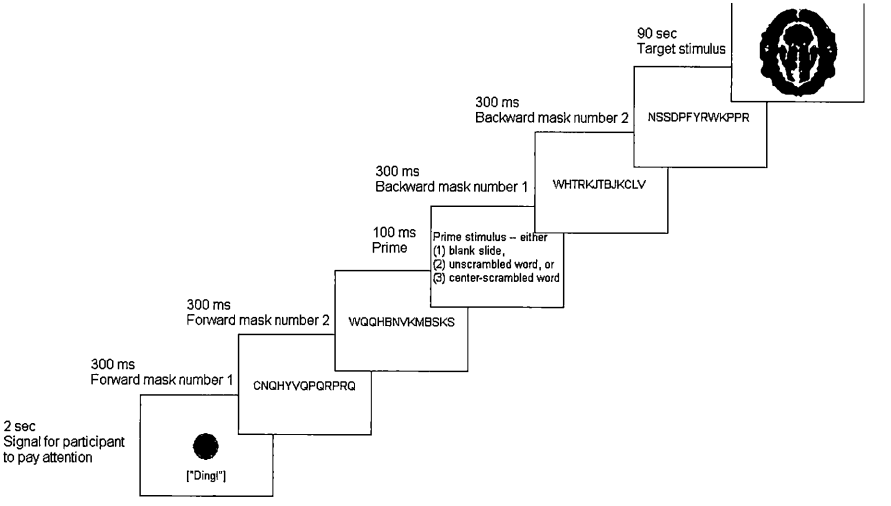

Figure 1. An example of the method used in the current study.

Figure 1 shows an example of the method. The experiment was conducted using Microsoft PowerPoint 2003. Participants were first shown a red dot (duration 2 s) on the overhead screen as a signal to pay attention. Two forward and two backward masks (duration 300 ms apiece), each a string of 13 consonants as in Abrams et al. (2002), appeared before and after the prime (duration 100 ms). In the control phase, the masking stimuli appeared before and after a blank slide (duration 100 ms). Finally, the inkblot appeared (duration 90 s) and the participants recorded what they saw in it. To make the 10 inkblots last for all 30 trials (10 control, 10 unscrambled primes, 10 center-scrambled primes), the inkblots were used right-side up, rotated 90 degrees to the left, and upside-down. Participants saw all the slides for one type of prime before advancing to the next type of prime. Conditions were Latin-square counterbalanced and consisted of three phases: (1) control, unscrambled, center-scrambled; (2) unscrambled, center-scrambled, control; and (3) center-scrambled, control, unscrambled.

RESULTS

Figure 2 depicts the mean (SD) number of inkblots participants described as containing sexual content. Panel A represents the women and Panel B represents the men. In all counterbalancing orders for the no prime condition, men tended to see more inkblots as sexual than did women. In two of three counterbalancing orders for both priming conditions, however, women tended to perceive more inkblots as containing sexual content than did men. All effects were observed through considerable variability except for the third counterbalancing order for men, in which there was only one participant and hence no standard deviation.

A 3 (counterbalancing order) x 2 (gender) x 3 (type of prime) mixed between-within subjects ANOVA was conducted to test priming effects. The results are shown in Table 2. Neither counterbalancing order (S; $F(2, 25) = 0.13$, $p = 0.88$), gender (G; $F(1, 25) = 0.01$, $p = 0.91$), nor type of prime (P; $F(2, 50) = 2.67$, $p = 0.08$) had any significant main effect. Similarly, no interaction effects were significant. Because the main effect of type of prime was marginally significant and collapsing across gender and counterbalancing condition showed the mean number of inkblots described sexually to be very similar for the unscrambled ($M = 4.97$, $SD = 3.10$) and center-scrambled ($M = 4.48$, $SD = 3.08$) priming phases, a post-hoc paired-samples t-test was conducted between the control and the unscrambled prime conditions. This analysis was significant, revealing a priming effect, $t(30) = -4.20$, $p = 0.0002$ (two-tailed).

DISCUSSION

The nonsignificant main effect of counterbalancing condition suggests that counterbalancing does not affect priming effects. Too few men participated in this study to draw any inferences about the effect of gender on priming effects. Importantly, because the words used in the current study were center-scrambled without concern either for morphemes or for vowel position, the similarity in the means of the unscrambled and center-scrambled priming phases somewhat contradicts Christianson et al.'s (2005) and Perea and Lupker's (2004) findings.

The marginal significance of the main effects of type of prime and the significance of the post-hoc t-test suggest that a priming effect was obtained in this study, a finding that contrasts with Spruyt et al.'s (2002) assertion. One reason for this effect might have been that the computers

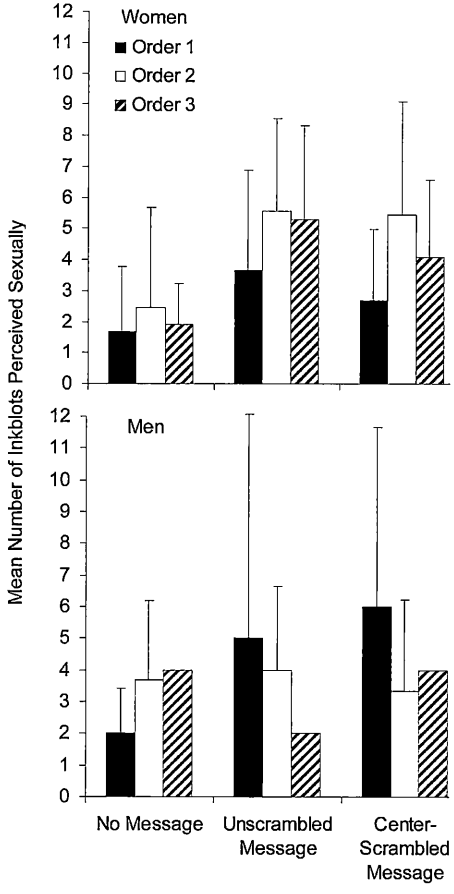

Figure 2. Average (SD) number of inkblots described as containing sexual content by counterbalancing order and type of prime. Panel A represents women and Panel B represents men.

and projectors used during experimental sessions were much slower than the computers and projectors used during the design phase of the study. This problem led to the masks and primes remaining on screen for longer than the planned durations, making it possible for the participants to read all the primes and eliminating the subliminal aspect of the priming. The timing problem might also have added in practice effects despite the use of counterbalancing. According to Abrams (2005), the greatest subliminal semantic priming effects occur when the primes have first been viewed supraliminally. Because the unscrambled and center-scrambled primes were the same words and were viewed clearly due to the timing problems, practice could account for the priming effect observed.

Table 2.

Analysis of Variance

Source	*df*	*F*	*p*
	Between subjects		
Session (S)	2	0.13	0.88
Gender (G)	1	0.01	0.91
S × G	2	0.47	0.63
Error	25	(16.28)	
	Within subjects		
Prime (P)	2	2.67	0.08
P × S	4	0.23	0.92
P × G	2	1.08	0.35
P × S × G	4	1.07	0.38
Error (P)	50	(5.13)	

One of the largest confounds in the current study was the aforementioned timing problems. Because 100 ms is both the shortest slide duration possible in the 2003 version of PowerPoint and the maximum recommended duration for subliminal stimuli (Greenwald & Abrams, 2000), PowerPoint is not recommended for future priming studies until technology improves significantly. Participants reported fatigue due to the long response duration when leaving the study, so future research should use a shorter response window. Based on observation of the participants during the sessions, it is suggested that 30 seconds is an optimal response window for a task such as this one.

Though the majority of participants responded that they had never heard anything about inkblot tests, they were primarily psychology majors who could have experience with other projective tests and might expect sexual content. The nonmatching stimulus modalities used also do not allow easy comparisons with the results of similar priming studies. An interesting offshoot of this experiment, based on Spruyt et al.'s (2002) assertion that pictures make better primes than words, would be to use sexually explicit pictures rather than words.

REFERENCES

Abrams, R. L. (2005). Unconscious processing of multiple nonadjacent letters in visually masked words [Electronic version]. Consciousness and Cognition, 14, 585–601. Retrieved February 8, 2007 from ScienceDirect database.

Abrams, R. L., & Greenwald, A. G. (2000). Parts outweigh the whole (word) in unconscious analysis of meaning [Electronic version]. Psychological Science, 11, 118-124. Retrieved March 13, 2007 from Academic Search Premier database.

Abrams, R. L., Klinger, M. R., & Greenwald, A. G. (2002). Subliminal words activate semantic categories (not automated motor responses) [Electronic version]. Psychonomic Bulletin & Review, 9, 100-106. Retrieved March 18, 2007 from http://faculty.washington.edu/agg/ pdf/Abrams_Klinger_Greenwald_PBR2002.pdf

American Psychological Association. (2002). Ethical principles of psychologists and code of conduct [Electronic version]. Retrieved October 18, 2006 from http://www.apa.org/ ethics/code2002.pdf

Christianson, K., Johnson, R. L., & Rayner, K. (2005). Letter transpositions within and across morphemes [Electronic version]. Journal of Experimental Psychology: Learning, Memory, and Cognition, 31, 1327-1339. Retrieved March 13, 2007 from Business Source Premier database.

Draine, S. C., & Greenwald, A. G. (1998). Replicable unconscious semantic priming. Journal of Experimental Psychology: General, 127, 286-303.

Duckworth, K.L., Bargh, J.A., Garcia, M., & Chaiken, S. (2002). The automatic evaluation of novel stimuli [Electronic version]. Psychological Science, 13, 513-519. Retrieved February 9, 2007 from Academic Search Premier database.

Ferguson, M. J., Bargh, J. A., & Nayak, D. A. (2005). After-affects: How automatic evaluations influence the interpretation of subsequent, unrelated stimuli [Electronic version]. Journal of Experimental Social Psychology, 41, 182-191. Retrieved February 8, 2007 from ScienceDirect database.

Grainger, J. & Whitney, C. (2004). Does the huamn mnid raed wrods as a wlohe? Trends in Cognitive Sciences, 8, 58-59.

Greenwald, A. G., & Abrams, R. L. (2000). Raindrop in a river: The paradox of ephemeral subliminal priming of evaluation [Electronic version]. Paper presented at the annual meeting of the Society for Personality and Social Psychology, Nashville, TN. (PowerPoint slides) Retrieved March 18, 2007 from http://faculty.washington.edu/agg/pdf/ GreenwaldAbrams.SPSP2000.PDF

Greenwald, A. G., Draine, S. C., & Abrams, R. L. (1996). Three cognitive markers of unconscious semantic activation [Electronic version]. Science, 273, 1699-1702. Retrieved February 8, 2007 from JSTOR database.

Hermans, D., Spruyt, A., De Houwer, J., & Eelen, P. (2003). Affective priming with subliminally presented pictures [Electronic version]. Canadian Journal of Experimental Psychology, 57, 97-114. Retrieved February 8, 2007 from Research Library Core database.

Jaśkowski, P., & Przekoracka-Krawczyk, A. (2005). On the role of mask structure in subliminal priming [Electronic version]. Acta Neurobiologiæ Experimentalis, 65, 409-417. Retrieved February 9, 2007 from http://www.nencki.gov.pl/pdf/an/vol65/4/4 _Jaskowski.pdf

Klauer, K. C., Mierke, J., & Musch, J. (2003). The positivity proportion effect: A list context effect in masked affective priming [Electronic version]. Memory & Cognition, 31, 953-967. Retrieved February 9, 2007 from IngentaConnect database.

Klauer, K. C., Roßnagel, C., & Musch, J. (1997). List-context effects in evaluative priming [Electronic version]. Journal of Experimental Psychology: Learning, Memory, and Cognition, 23, 246-255. Retrieved March 18, 2007 from http://www.psycho.uni-duesseldorf.de/abteilungen/ddp/Dokumente/Publications/1997.KlauerRossnagelMusch. ListContextEffects.JEPLMC.pdf

Kouider, S. & Dupoux, E. (2004). Partial awareness creates the "illusion" of subliminal semantic priming [Electronic version]. Psychological Science, 15, 75-81. Retrieved February 8, 2007 from Academic Search Premier database.

Perea, M., & Lupker, S. J. (2004). Can CANISO activate CASINO?: Transposed-letter similarity effects with nonadjacent letter positions [Electronic version]. Journal of Memory and Language, 51, 231-246. Retrieved April 27, 2007 from ScienceDirect database.

Rayner, K. & Kaiser, J. S. (1975). Reading mutilated text. Journal of Educational Psychology, 67, 301-306.

Rayner, K., White, S. J., Johnson, R. L., & Liversedge, S. P. (2006). Raeding wrods with jubmled lettres: There is a cost [Electronic version]. Psychological Science, 17, 192-193. Retrieved January 23, 2007 from Blackwell Synergy database.

Spruyt, A., Hermans, D., De Houwer, J., & Eelen, P. (2002). On the nature of the affective priming effect: Affective priming of naming responses [Electronic version]. Social Cognition, 20, 227-256. Retrieved February 9, 2007 from Research Library Core database.

Storbeck, J. & Robinson, M. D. (2004). Preferences and inferences in encoding visual objects: A systematic comparison of semantic and affective priming [Electronic version]. Personality and Social Psychology Bulletin, 30, 81-93. Retrieved February 8, 2007 from EJS database.

Thomas, L. A., & LaBar, K. S. (2005). Emotional arousal enhances word repetition priming [Electronic version]. Cognition and Emotion, 19, 1027-1047. Retrieved February 8, 2007 from Academic Search Premier database.

Visser, T. A. W., Merikle, P. M., & Di Lollo, V. (2005). Priming in the attentional blink: Perception without awareness? [Electronic version]. Visual Cognition, 12, 1362-1372. Retrieved February 9, 2007 from Academic Search Premier database.

Impacts of Davisco's Lake Norden Cheese Plant

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ABSTRACT

This paper addresses the regional impact of the Davisco Foods International cheese plant in Lake Norden, South Dakota. Since opening in November 2003, the $40 million plant has exerted a growing influence on dairying throughout eastern South Dakota and adjacent areas, as well as influencing the community of Lake Norden, the cultural landscape, the economy, and the environment in various ways. Each topic is investigated from a geographic perspective based primarily on field research. As the plant continues to expand, its impact on the covered topics deepens, both negatively and positively.

INTRODUCTION

In November, 2003, Davisco Foods International opened a $40 million cheese plant in the small South Dakota community of Lake Norden. Davisco, a firm that has owned and operated a food ingredient plant in Lake Norden since 1983, announced plans to build the new cheese plant in late 2001. This multi-million dollar operation affects both the community and region economically, environmentally, and in other ways. Mark Davis, CEO of Davisco stated, "This is a major investment. . .[one] that represents an expanded partnership between the state of South Dakota, Lake Norden, Davisco, Land O'Lakes, and area milk producers." Land O'Lakes, which markets the cheese made in Lake Norden, partnered with Davisco in milk purchasing for the plant. The Davisco operation also has given area farmers a steady and reliable market for milk.

Lake Norden was chosen as the site of the new cheese plant for various reasons. The food ingredient plant, which processes whey, was already located in the community. Before the cheese plant was built, the food ingredient plant received whey from several other South Dakota cheese plants, including Land O'Lakes in Volga (prior to its shutting down several years ago), Cass Clay in Hoven, and Dairy Concepts in Pollock. Building the cheese plant in Lake Norden would reduce the need to transport whey from these other plants. Another factor contributing to the Lake Norden site was the close proximity of Interstate 29, located 24 miles to the east. This makes trucking the milk in and cheese out more efficient. Additionally, the greatest number of dairy farms are located in Eastern South Dakota close to the I-29 corridor (Figure 1).

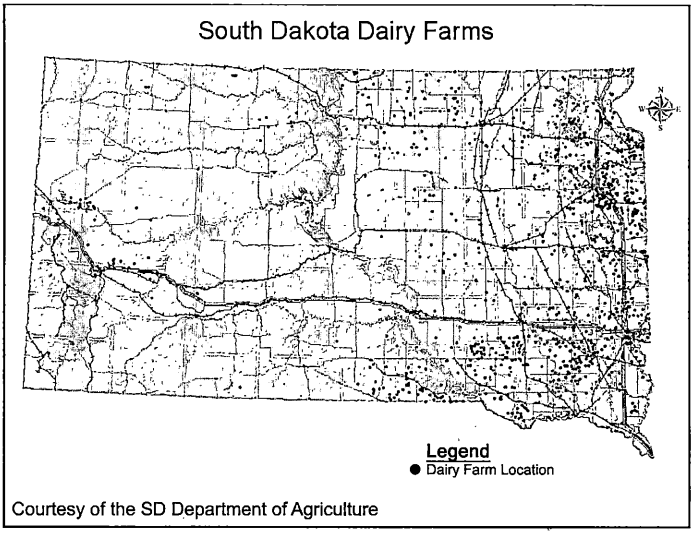

Figure 1.

With all the perishable milk received on a regular basis, the Lake Norden Cheese Plant, in order to keep up with its supply, is in production 21 hours per day. Currently, 40 to 50 milk trucks bring in about 2.3 million pounds (approximately 270,000 gallons) of milk daily. When the plant first opened in 2003, it processed about 1.2 million pounds of milk daily. In 2004, the amount increased to 1.8 million pounds per day, resulting in a doubling of production over a four year period. Davisco's ultimate goal is to expand to five million pounds of milk processed daily, slightly more than double the current production. In the spring of 2007, the plant produces approximately 200,000 pounds of cheese daily, most of which is mozzarella. The cheese is produced in large blocks that are then cut into smaller pieces that are distributed in 6, 10, or 20 pound packages.

The plant sends out approximately 12 to 15 trucks of cheese daily, Monday through Friday. The product is delivered throughout South Dakota and much of the United States to companies such as Papa Murphy's, Schwan's, and Kraft. Marketing plans currently are underway to begin exporting cheese to South Korea.

The Lake Norden Cheese Plant is fairly new and is expanding its operation. As this occurs, the company continues to expand its impact on the region's economy, environment, and landscape in various ways.

RESULTS

Economy

When a $40 million operation comes into a small community, such as Lake Norden with a population of approximately 450, it is bound to have a profound economic impact

on the town and its people. The Lake Norden Cheese Plant has affected the economy of the town, region, and state. Before the cheese plant was built, Davisco employed 80 people in its food ingredient operation that dried whey. With the addition of the cheese plant, 100 new jobs were created. Only about 10% of the employees live in Lake Norden; the remainder of them comes from rural areas or communities within a radius of approximately 40 miles. With the creation of new jobs, more money is being put into circulation, which in turn benefits the local economy. The two-week wages for the plant's hourly employees is approximately $185,000. In April of 2007, the plant began the second phase of a $10 million expansion. When completed, even more employees will be needed, although the number is undisclosed by the firm.

Environment

Some concern has been expressed regarding the plant's affects upon the environment, both directly and indirectly. The plant itself produces a considerable amount of effluent—treated waste water—that must be held in ponds until it evaporates. There are eight holding ponds, occupying an area of approximately 160 acres, located just south of Lake Norden. Initially, local concern was limited primarily to the odor created by the ponds, which was most evident within the community with a southerly wind. Tests conducted by the Department of Environment and Natural Resources (DENR) have found small levels of hydrogen sulfide that produce a noxious odor similar to that of rotten eggs. This gas is attracted to moisture, so it often is referred to as a swamp gas. Hydrogen sulfide is produced under an anaerobic state, one that does not require oxygen, and although the holding ponds were designed to be aerobic—meaning there are bacteria that require oxygen to break materials down—somehow the gas is being emitted into the air. The smell tends to be overwhelmingly strong because hydrogen sulfide tends to settle in low spots, and because it is a heavy gas, it dissipates very slowly, if at all. Davisco has indicated that the ponds are secreting gasses they did not expect, and they have been actively searching for a solution to the problem. In March of 2007, the company indicated plans to place environmental "blankets" over the ponds. These "blankets" would resemble the appearance of the Metrodome in Minneapolis, but at a smaller scale. When the pressure from the gasses built up, equipment called scrubbers would burn the gasses off.

Another matter that has caused some local concern is that sodium levels are rising in nearby sloughs and fields. Treated waste water from the plant is sent to the holding ponds, and then to the waste water treatment plant. After the water is treated, it is moved to the aerobic respirator. Before it can be dumped into the constructed wetlands, dissolved oxygen level (DO) of 8 must be reached. The waste water put in the holding ponds only needs a DO of 2, but because the water in the constructed wetlands is designed to gradually leak back into the groundwater, the water must be completely treated and of sound quality. The wetlands are lined with clay, which is designed to filter out the sodium while the water slowly leaks back into the aquifer. Tests have been conducted on the water in nearby sloughs, and it has been found that they contain considerably higher amounts of sodium than normal. Flora in the vicinity of the sloughs has been negatively impacted by the toxic water. A normal water supply has a sodium content of approximately 50-200 parts per million, and to be considered a fresh body of water, the

concentration has to be less than 1000 parts; sloughs near the Lake Norden area were tested with levels between 800 and 1600 parts per million. When these high sodium levels are secreted, they sterilize the ground, thereby prohibiting crop growth. Davisco is aware of this problem, and is considering options by which the sodium problem can be solved.

There also has been concern expressed over the negative impact that bigger dairy operations may have on land and water resources. The Department of Environment and Natural Resources, however, has not documented any ill-effects on water or land resources. As an environmental safeguard, any dairy with 700 or more cows must meet the requirements of the department's general water pollution control permit for concentrated animal feeding operations. This permit ensures the protection of the state's surface and ground waters by establishing minimum environmental standards for regulated livestock operations. There also are many zoning regulations set by each county to ensure environmentally safe conditions.

Landscape

The Lake Norden Cheese Plant has had a considerable impact on the area's cultural landscape. The community itself has experienced dramatic landscape changes. From a distance, people approaching the community can not help but notice the plant's "towers" rising above the rest of the buildings and trees. Upon entering the town, the plant's gray walls now form a massive backdrop. Lake Norden's Main Street has undergone considerable renovation during recent years. With the addition of the cheese plant, the street has taken on a rather "corporate" appearance. When construction on the plant began in 2002, so did construction of a new road along the south and west side of town. It was built to allow truck drivers going to and from the cheese plant to bypass the town while also providing better access to the plant. Instead of going through the town where they would increase traffic and thereby pose a safety hazard, break up the streets, and contribute to both sound and exhaust pollution, most truck drivers use the bypass. Driving south out of town, where the landscape used to be one dominated by open fields, the plant's eight holding ponds and constructed wetlands now occupy an area of about 300 acres.

New and larger dairy operations have been built across the state. These new farms have a different appearance than the traditional small, family owned and operated dairy farm with perhaps a dozen to fifty cows. In smaller dairy operations, the cows are sometimes pastured, but on the bigger dairy operations, they are usually confined in the huge barns or adjacent dry lots year round.

Regional Impacts

For years, the number of dairy cows and dairy operations in South Dakota had been decreasing. When Davisco announced plans for the cheese plant, it was anticipated that milk from 65,000 cows would be needed. With dairy farmers knowing there was a demand for raw milk, cattle numbers gradually started to rise in 2005. Hamlin County, in which Lake Norden is located, and other nearby counties such as Kingsbury and Brookings, actually began to experience an increase in the number of dairy cattle in 2004.

Although the number of dairy cows in South Dakota has actually decreased by about 14,000 since 2000, according to the USDA National Agricultural Statistics Service, milk

produced per cow has increased dramatically from 15,516 to 18,580 pounds per year, an annual increase of a little over 3,000 pounds of milk per cow (Figure 2). This increase has had a very positive impact on the total production of milk throughout the state, which has also risen since 2000 (Figure 3).

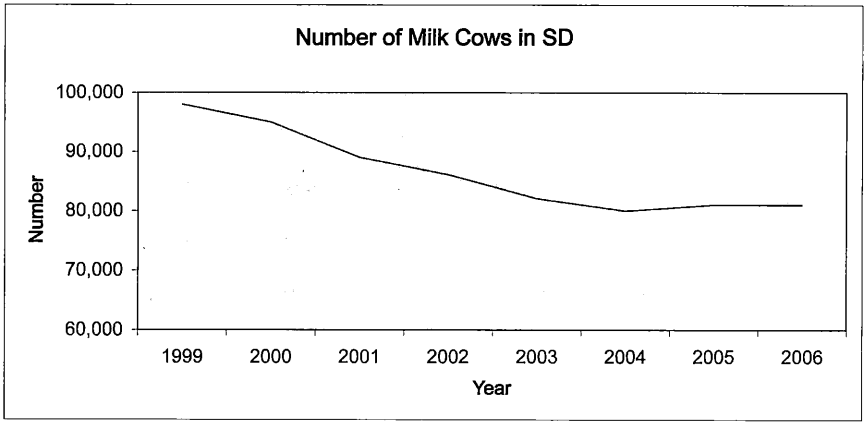

Figure 2

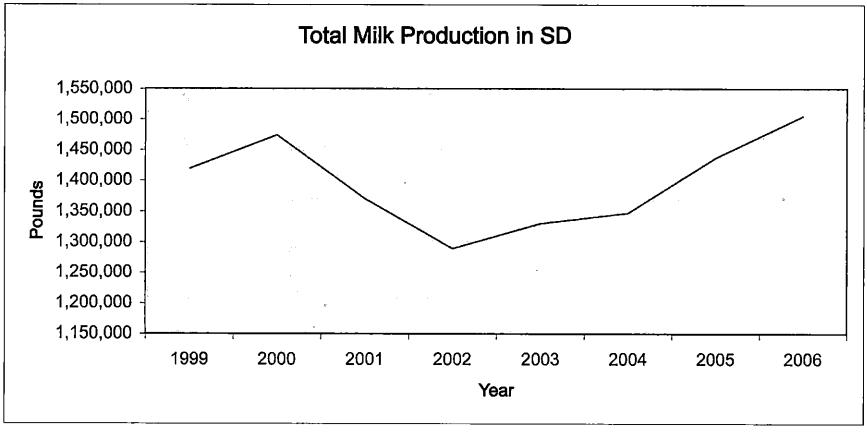

Figure 3

There has not been an increase in the state's number of dairy farms. In 2003, there were 778 farms and in 2006 the number had dropped to 601 operations, a loss of 177 dairy operations over a three year period. This trend of fewer operations and numbers of dairy cows reflects what is happening nationwide. In John Cross's article "Restructuring America's Dairy Farms," he acknowledges that dairy operations have decreased steadily between the years 1992 and 2002. The exception is herds of 500 or more cows, which

have experienced an increase over the past decade (Figure 4). South Dakota's case is very similar to that of the national average. Since 2000, herds of 200 or more cows have increased, while smaller herds continue to decline (Figure 5). But because of better technology, feed, and management, milk production per cow has increased.

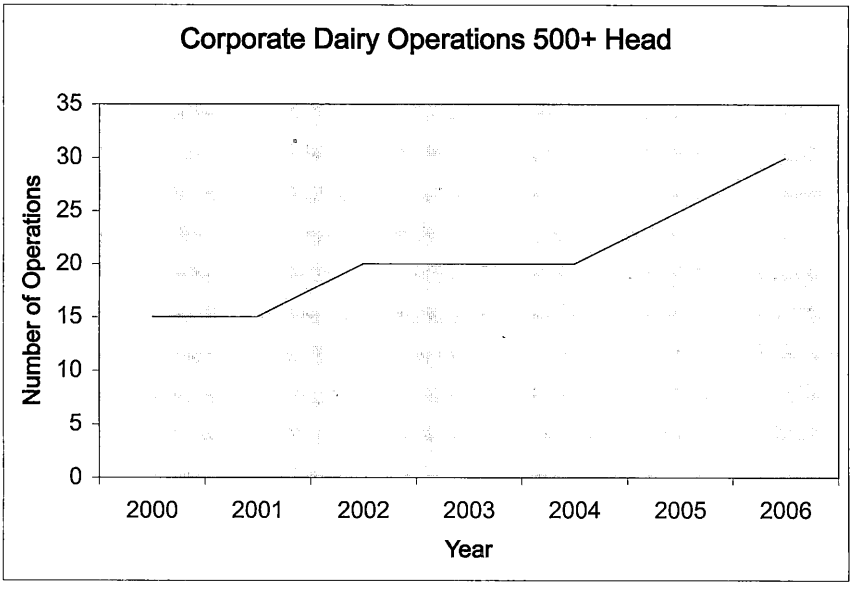

Figure 4

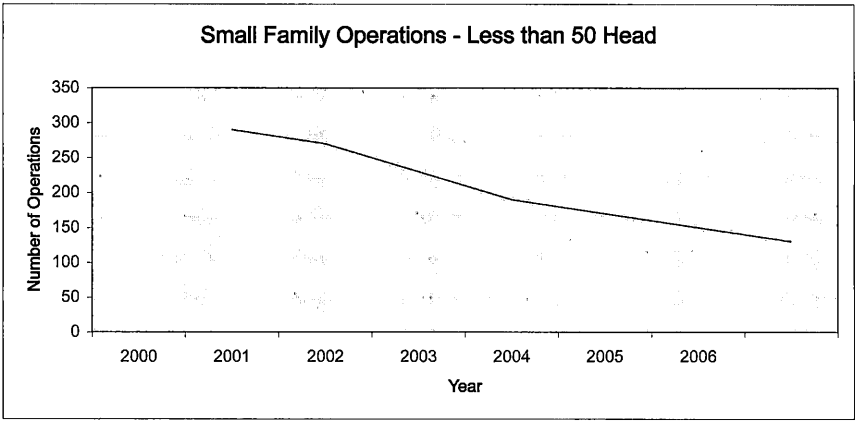

Figure 5

The Lake Norden Cheese Plant purchases milk from all over the state of South Dakota, southwestern Minnesota, northwestern Iowa, and condensed milk from Davisco's plant in Jerome, Idaho. South Dakota supplies 90% of the milk needed for the cheese plant to run at maximum capacity. Currently, milk is taken from about 30,000 cows, which as of now is the plant's maximum capacity. In April 2007, work began on a $10 million expansion project which includes the addition of new equipment that will increase the capacity by an additional 10,000 cows. Eventually, the plant's goal is to expand and use milk from 75,000 cows. According to 2005 data from the USDA, there are approximately 81,000 head of dairy cows in South Dakota. If the Lake Norden Cheese Plant is to achieve its goal of 75,000 cattle, the state will have to either raise more dairy cattle, or the plant will need to extend its milkshed and bring in more milk from outside the state.

CONCLUSIONS

The Lake Norden Cheese Plant has been in operation since 2003, or for nearly four years. During this relatively short period, it has had a considerable impact on the region's economy, environment, and landscape. Each month, hundreds of thousands of dollars are put into circulation in the economy. Davisco is continually searching for ways to ensure that the environment is not negatively impacted. With the physical plant structure, the roads, the holding ponds, and the surrounding dairy farms, the landscape continues to be altered in many ways. Currently, the Lake Norden Cheese Plant collects most of the milk it needs from dairies in South Dakota, Minnesota, and Iowa. The majority of the milk it collects does come from South Dakota. The plant hopes to expand to full production capacity sometime in the near future, which means it must double the number of cows from which milk currently is obtained. To obtain the amount of milk needed, the plant will probably have to expand the region from which it is acquired. With this expansion, however, new jobs will be created. The Lake Norden Cheese Plant has impacted the community, surrounding area, and state from its beginning, and it will certainly continue to do so in the future as the company continues to expand.

REFERENCES

Andrews, Janet (18 February 2007, Lake Norden, SD). Interview by author.

Cross, John A. (2006). Reconstructing America's dairy farms. The Geographical Review, 96(1), 1-23.

Layman, John (21 March 2007, Lake Norden, SD). Phone interview by author.

Pederson, Mark (February – March 2007, Lake Norden, SD). Email correspondence and in-person interview by author.

South Dakota, Department of Agriculture

United States Department of Agriculture, National Agricultural Statistics Services

Modeling Immune Response to Bacterial Infection

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INTRODUCTION

Mathematical models have begun to play an important role in the study of biology. We will examine this role further by analyzing a specific model of the innate immune system's response to a bacterial infection. Beginning with the biological background of the model, we will move into an explanation of a specific model of this situation followed by a critique of the model and future work to be done with the topic.

The human body faces invasion from infectious agents including viruses and bacteria on a daily basis [6]. The human body in turn has various defense systems in place to counteract the daily threat from infectious agents and foreign material trying to enter the body's otherwise sterile environment. When an infectious agent first enters the body, the body's sensory systems alert its own cells known as host cells to the presence of the foreign material. The sensors then aid in guiding other host cells to the location of the infectious agent and initiating the process of destroying the foreign material. This form of defense against infectious agents plays a major role in the body's innate immunity [5]. Innate immunity is inborn and its effectiveness is independent of whether or not the body has been previously exposed to a given infectious agent [6].

Working with the body's innate immunity, the adaptive immune response specializes in recognizing particular infectious agents and developing specific antibodies to destroy them. While the innate immunity's defenses take action when foreign material gains access to the body despite the material's makeup, the reaction of the adaptive immune response is dependent upon whether or not the body has encountered the specific infectious agent before and if so, how many times the body has encountered it [5].

After being exposed to an infectious agent, the adaptive immune response works to produce antibodies to help recognize and destroy that specific type of infectious agent within the body. The adaptive immune response in turn becomes more efficient in destroying specific infectious agents after it has been exposed to the agents. The down side is that recognizing infectious agents and producing specific antibodies takes time. During this time the infectious agents may cause damage to the body or even death [5].

Due to the amount of time the adaptive immune response requires and its complex nature, we will focus on the innate immunity's response to a bacterial infection and specifically on its two major components: neutrophils and macrophages. Neutrophils and macrophages are both phagocytes, cells that specialize in destroying foreign material via ingestion. Macrophages and neutrophils circulate throughout the body ingesting foreign particles they encounter. In the case of an infection, damaged cells or macrophages that

have ingested foreign particles will release specific chemical signals within the body called cytokines to recruit the help of other phagocytes. One of the body's primary reactions to an infection, inflammation aides in the process of containing and destroying an infection [5].

Neutrophils possess a vital role during early inflammation. Produced in the bone marrow, neutrophils live for only 8 to 20 hours, while neutrophils recruited to fight an infection in the tissue undergo chemical changes that allow them to live for several days. Although neutrophils are short-lived, they still remain a dominant player in the innate immune response and account for 40 to 60 percent of the white blood cells found in the body. During an infection, the concentration of the neutrophils can increase up to tenfold to help fight off the infection [3].

Contrary to the short-lived neutrophils, macrophages live for weeks to months. Also produced in the bone marrow, blood monocytes experience changes as they leave the bloodstream and enter the body's tissues as macrophages. While in the tissue, macrophages may undergo changes to become active macrophages. Active macrophages have an increased killing power and are able to more easily recognize and digest foreign material. Macrophages play a role in both the innate immune response and the adaptive immune response recognizing and destroying foreign material [5]. We will focus solely on the macrophages role in the body's innate immune response.

We will now move on to explore a mathematical model of this situation presented in the paper "Release kinetics and cell trafficking in relation to bacterial growth explain the time course of blood neutrophils and monocytes during primary Salmonella infection." In a recent paper Takumi, Garssen, et al, make use of both their own and others' experimental data to create a system of differential equations to model the effects a bacterial infection has on neutrophil and macrophage concentrations [7]. The authors use the model to calculate the probability that the infected host's innate immune responses are overrun and the host becomes ill [7]. The following is an explanation and listing of the differential equations involved in this model. Note all of the individual terms and parameters in the equations are positive, B represents the concentration of bacteria, and capitalized letters represent concentrations that vary over time whereas lowercase letters represent constant values. A formal listing of the parameters used, their meanings, and their values can be found in Appendix A.

Equations (1) and (2) below model the individual concentrations of the neutrophils in the blood and in the tissue. Contrary to the neutrophils, macrophages possess three different states and equations (3), (4) and (5) represent the individual concentrations of the blood monocytes, tissue macrophages, and activated macrophages.

Rate of change of concentration of blood neutrophils = Rate of neutrophil release from bone marrow + Maximum neutrophil release rate in infection - Death rate of blood neutrophils - Migration rate of neutrophils from blood to tissue

$$\frac{d}{dt}N_b = s_1 + \frac{s_2 B^{n_1}}{h_1 + B^{n_1}} - d_1 N_b - \frac{k_1 N_b B^{n_2}}{h_2 + B^{n_2}} \quad (1)$$

Rate of change of concentration of tissue neutrophils = Migration rate of neutrophils from blood to tissue - Death rate of tissue neutrophils

$$\frac{d}{dt}N_t = \frac{k_1 N_b B^{n_2}}{h_2 + B^{n_2}} - d_2 N_t \quad (2)$$

Rate of change of concentration of blood monocytes = Rate of monocyte release from bone marrow + Rate of maximum monocyte release in infection - Death rate of blood monocytes - Migration rate of blood monocytes to tissue macrophages - Migration rate of blood monocytes to tissue macrophages in infection

$$\frac{d}{dt}M_b = s_3 + \frac{s_4 B^{n_3}}{h_3 + B^{n_3}} - d_3 M_b - k_2 M_b - \frac{k_3 M_b B^{n_4}}{h_4 + B^{n_4}} \quad (3)$$

Rate of change of concentration of tissue macrophages = Migration rate of blood monocytes to tissue macrophages + Migration rate of blood monocytes to tissue macrophages in infection - Death rate of tissue macrophages - Activation rate of tissue macrophages to activated macrophages in

$$\frac{d}{dt}M_t = k_2 M_b + \frac{k_3 M_b B^{n_4}}{h_4 + B^{n_4}} - d_4 M_t - cM_t B \quad (4)$$

Rate of change of concentration of activated macrophages = Activation rate of tissue macrophages to activated macrophages in infection - Death rate of activated macrophages

$$\frac{d}{dt}M_a = cM_t B - d_5 M_a \quad (5)$$

Rate of change of bacteria population = Growth rate of bacteria - Rate of phagocytosis by tissue neutrophils - Rate of phagocytosis by tissue macrophages - Rate of phagocytosis by activated macrophages

$$\frac{d}{dt}B = rB - z_1 N_t B - z_2 M_t B - z_3 M_a B \quad (6)$$

The relationship between the parameters and the concentration of the neutrophils and the macrophages is represented pictorially in Figure 1 (A) and (B). Within Figure 1 solid arrows represent the movement of phagocytes in the absence of infection and dashed arrows represent the movement of additional phagocytes that are present during an infection. Note a major difference between neutrophils and macrophages exists in that tissue macrophages possess a baseline source plus an additional source in the presence of an infection, as opposed to the tissue neutrophils where migration occurs only in the presence of an infection. Relating both the neutrophil and macrophage concentrations,

equation (6) introduces a per capita growth rate for the bacteria (r) along with per capita rates of phagocytosis for the neutrophils and macrophages. Note the rate of change of the bacterial concentration in equation (6) depends upon a single source and individual death terms for each type of phagocyte present at the sight of the infection.

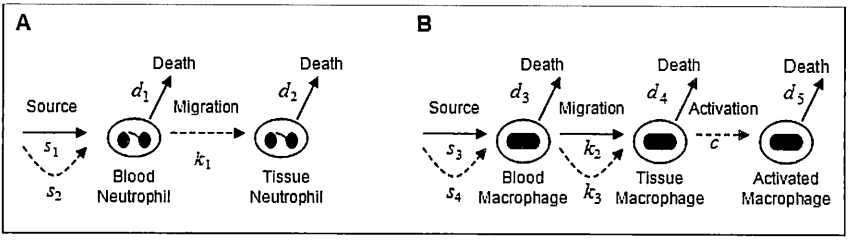

Figure 1

As an initial condition for the set of equations, we assume the bacteria concentration is equal to zero, such the $B(0)=0$. We consider this initial state a "healthy equilibrium" since it represents the case in which the body is free of harmful bacteria.

When $B(0)=0$, we assume the individual concentrations of neutrophils and macrophages are constant since no additional neutrophils or macrophages are being recruited in the absence of an infection. If the rates of change of the individual concentrations of neutrophils and macrophages are constant, then the rates of change of these concentrations are equal to zero. As a result, the left hand sides of equations (1) through (5) are equal to zero. With the left hand sides of equations (1) through (5) set equal to zero, we can solve the equations algebraically to determine the initial conditions of each variable while keeping in mind $B(0)=0$.

Thus, $N_b(0)=\frac{s_1}{d_1}$, $N_t(0)=0$, $M_b(0)=\frac{s_3}{d_3+k_2}$, $M_t(0)=\frac{k_3 s_3}{d_4(d_2+k_2)}$ and $M_a(0)=0$.

Note the initial concentrations of the tissue neutrophils and tissue macrophages align with the fact that tissue macrophages possess a baseline source and tissue neutrophils do not possess a baseline source as displayed in Figure 1 and equations (2) and (4).

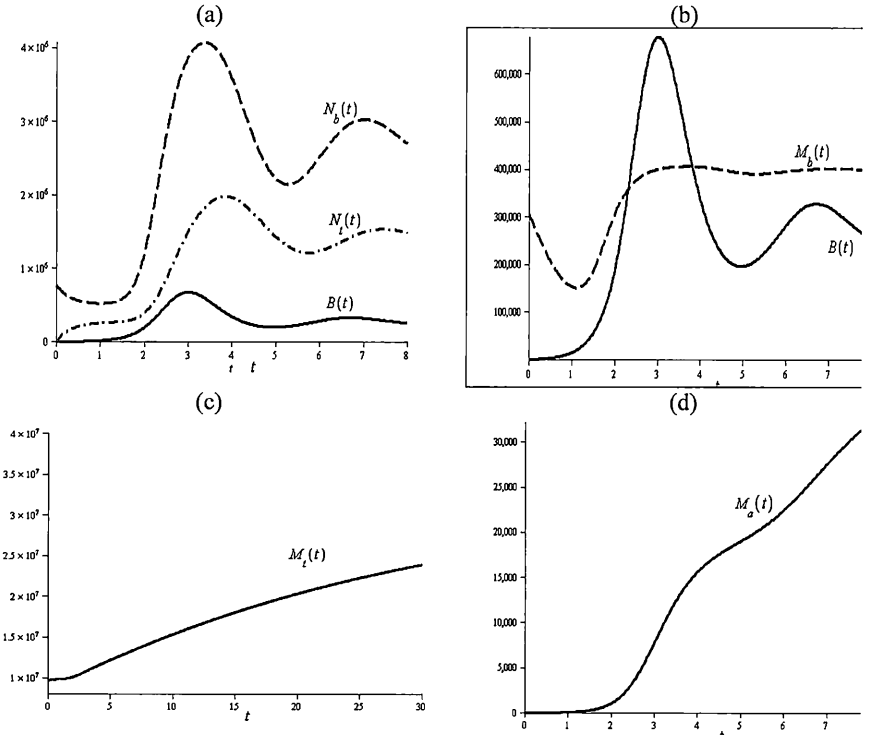

Figure 2. Numerical Solution of Equations (1)-(6)

Using parameter values as given in [7] (listed in Appendix A), a numerical solution to equations (1)-(6) is easily obtained. The graphs of the concentrations of bacteria, neutrophils and macrophages are then plotted over time. An initial value of B(0)=1000 was chosen. As can be seen in Figure 2a, an increase in the concentration of the bacteria is followed by an increase in the blood and tissue neutrophil concentrations, which results in a slight dip in the bacteria concentration. As time continues, the concentration of the bacteria begins to level off but stays above zero representing an unhealthy state. A similar relationship can exist with the blood monocytes and activated macrophages (See Figure 2b). The corresponding graph of tissue macrophages and activate tissue macrophages are displayed in Figures 2c and 2d.

Although the system of differential equations represented by equations (1) through (6) may accurately represent the innate immune response in specific situations, one will find various problems within the model upon further review. Analyzing the rate of change of the bacterial concentration as represented by equation (6), we discover given that a specific per capita growth rate of the bacteria, *r*, the bacteria may grow exponentially without bound. Bacteria cells multiply via binary fission; meaning a bacteria cell replicates all of its cell parts and then divides into two individual cells [5]. The time it

takes for a bacteria cell to duplicate itself depends upon the type of bacteria [5]. In general, a bacteria population can grow exponentially without bound given an unlimited amount of resources and space [5]. The current model allows for such an environment, whereas in the real world such an environment does not exist.

To analyze the possibility of unlimited exponential bacteria growth further we will prove the model allows for such a possibility as outlined in Proposition 1.

Proposition 1. *If* $r > z_1 N^* + \max(z_2, z_3) M^*$ *with*

$$N^* = \frac{k_1(s_1 + s_2)}{d_1 \cdot d_2} \text{ and } M^* = \frac{s_3 + s_4}{\min(d_3, d_4, d_5)},$$

then $B(t) \geq B(0)e^{r_0 t}$ *for some* $r_0 > 0$ [original to paper].

We will delay the proof of Proposition 1 until after a brief explanation of the processes involved in the proof. Proposition 1 states if the per capita growth rate for bacteria, r, is greater than an upper bound for the amount of bacteria being destroyed by all neutrophils and all macrophages, $z_1 N^* + \max(z_2, z_3) M^*$, for specific upper bounds on the concentration of neutrophils and macrophages, then the bacteria population is growing at a rate equal ~~than~~ exponential growth.

We will first show an upper bound exists for the concentration of both the neutrophils and the macrophages. Then we will use these upper bounds to establish the existence of a threshold value for r such that $\frac{d}{dt} B > 0$, the rate of change in the concentration of bacteria is greater than zero. Finally, we will use the threshold value for r to show $B(t) \geq B_0 e^{r_0 t}$ where $r_0 = r - z_1 N^* - z_3 M^*$. Note the upper bound values created, N^* and M^*, are crude upper bounds of the functions and lower maximum values may exist. The following lemma will be used within the proof of Proposition 1 to establish upper bounds for the neutrophil and the macrophage concentrations.

Lemma 1. *For a function* $z(t)$ *with* $z(0) > 0$ *and real numbers* $a, b > 0$:

1. *If* $\frac{dz}{dt} \geq bz$, *then* $z(t) \geq z(0)e^{bt}$ *for all* $t \geq 0$.
2. *If* $\frac{dz}{dt} \leq a - bz$ *with* $a > 0$ *and* $z(0) < \frac{a}{b}$, *then* $z(t) \leq \frac{a}{b}$ *for all* $t \geq 0$.

Proof of Lemma 1. Both statements will be proven using the well-known theorem if f, g are continuous and $f(w) \leq g(w)$ for all $w \in R$, then $\int_a^b f(w)\, dw \leq \int_a^b g(w)\, dw$ [1].

1. Let b be a real number such that $b > 0$. Assume $\frac{dz}{dt} \geq bz$ for some function $z(t)$. It follows from $\frac{dz}{dt} \geq bz$ that $\frac{dz}{dt}\frac{1}{z} \geq b$, which can be rewritten as $\frac{d}{dt}[\ln z(t)] \geq b$. Applying the theorem to the inequality $\frac{d}{dt}[\ln z(t)] \geq b$ results in

$\int_0^t \frac{d}{dt}[\ln z(t)]\,dt \geq \int_0^t b\,dt$. Then it follows $\ln z(t) - \ln z(0) = \ln\frac{z(t)}{z(0)} \leq bt$. Since $b > 0$, taking the exponential of each side of the inequality will still maintain the inequality. Hence, $e^{\ln[z(t)/z(0)]} \geq e^{r_0 t}$ and as a result $z(t) \geq z(0)e^{rt}$ for all $t \geq 0$.

2. Let a, b be real numbers such that $a > 0$ and $b > 0$. Assume $\frac{dz}{dt} \leq a - bz$ with $z(0) < \frac{a}{b}$ for some function $z(t)$. Then it follows from $\frac{dz}{dt} \leq a - bz$ that $\frac{dz}{dt} + bz \leq a$. Multiplying by an e^{bt} we obtain $e^{bt}\left(\frac{dz}{dt} + bz\right) \leq e^{bt}a$, which can be rewritten as $\frac{d}{dt}(e^{bt}z) \leq e^{bt}a$. Applying the theorem to $\frac{d}{dt}(e^{bt}z) \leq e^{bt}a$ we obtain $\int_0^t \frac{d}{dt}(e^{bt}z)\,dt \geq \int_0^t e^{bt}a\,dt$. As a result, $e^{bt}z(t) - e^0 z(0) \leq \frac{a}{b}(e^{bt} - 1)$. Multiplying the inequality by e^{-bt} results in $z(t) - z(0)e^{-bt} \leq \frac{a}{b} - \frac{a}{b}e^{-bt}$. Thus from $z(0) < \frac{a}{b}$ we obtain $z(t) \leq e^{-bt}(z(0) - \frac{a}{b}) + \frac{a}{b} \leq \frac{a}{b}$. Then it follows from $a > 0$ and $b > 0$ that $\frac{a}{b} > 0$, and as a result $z(t) \leq \frac{a}{b}$ for all $t \geq 0$. Q.E.D.

Proof of Proposition 1. To establish an upper bound for the neutrophil concentration, N^*, add the right hand sides of (1) and (2) which results in

$$\frac{d}{dt}(N_b + N_t) = s_1 + s_2\frac{B^{n_1}}{h_1 + B^{n_1}} - d_1 N_b - d_2 N_t$$
$$\leq s_1 + s_2 - \min(d_1, d_2)\cdot(N_b + N_t).$$

Let $N(t) = N_b(t) + N_t(t)$. Then by the second part of Lemma 1 with $a = s_1 + s_2$, $b = \min(d_1, d_2)$ and $z(t)=N(t)$ it follows that

$$N_t(t) \leq \mathrm{N}(t) \leq \frac{s_1 + s_2}{\min(d_1, d_2)}$$

for all $t \geq 0$. As a result $N^* = (s_1 + s_2)/\min(d_1, d_2)$ is an upper bound for the neutrophil concentration in the infected tissue.

To establish an upper bound for the macrophage concentration, M^*, add the right hand sides of (3), (4) and (5) which results in

$$\frac{d}{dt}(M_b + M_t + M_a) = s_3 + s_4\frac{B^{n_2}}{h_3 + B^{n_2}} - d_3 M_b - d_4 M_t - d_5 M_a$$
$$\leq s_3 + s_4 - \min(d_3, d_4, d_5)\cdot(M_b + M_t + M_a).$$

Let $M = M_b + M_t + M_a$. Then by the second part of Lemma 1 with $a=s_3+s_4$, $b = \min(d_3, d_4, d_5)$ and $z(t)=M(t)$ it follows that

$$M_a + M_t \le M(t) \le \frac{(s_3 + s_4)}{\min(d_3, d_4, d_5)}$$

for all $t \ge 0$. As a result $M^* = (s_3 + s_4)/\min(d_3, d_4, d_5)$ is an upper bound for the macrophage concentration in the infected tissue.

To establish a threshold value for r such that $\frac{d}{dt}B > 0$ we will first rewrite equation (6) as $\frac{d}{dt}B = B(r - z_1 N_t - z_2 M_t - z_3 M_a)$. Note $B(0)>0$ because a negative amount of bacteria is not possible and if no bacteria is present at time $t=0$, then the $B(t)=0$ for all $t \ge 0$. Then the established upper bounds for the neutrophil and macrophage concentrations imply

$$\frac{d}{dt}B \ge B(r - z_1 N^* - \max(z_2, z_3)M^*).$$

As a result $\frac{d}{dt}B > 0$ whenever $r > z_1 N^* + \max(z_2, z_3)M^*$. Now define

$$r_0 = r - z_1 N^* - \max(z_2, z_3)M^*.$$

Now assume that $r_0 > 0$ and we obtain

$$\frac{d}{dt}B = B(r - z_1 N_t - z_2 M_t - z_3 M_a)? \ge r_0 B > 0.$$

If $B(0) > 0$, by the first part of Lemma 1 with $b=r_0$ and $z(t)=B(t)$, it follows that $B(t)? \ge B(0)e^{r_0 t}$. Therefore, $B(t)$ is greater than exponential growth and the population of the bacteria grows at a rate equal to or greater than exponential growth. Q.E.D.

The proof of Proposition 1 mathematically outlines the possibility of unlimited bacteria growth within the current model. Given a specific per capita growth rate of the bacteria, r, the bacteria may grow exponentially without bound. This contradicts the real world situation in which numerous factors including the environment in which the bacteria resides affects the bacteria's growth. As a result for large per capita bacteria growth rates (large r), a model that considers a limited growth factor for the bacteria would more accurately reflect what occurs in the real world situation of bacterial infections. Combining the original growth term rB with a limiting growth factor $1-B/k$ for some constant k, would produce a source term of $rB(1-B/k)$ that more accurately represents the eventual leveling off of the exponentially growing bacteria population. To determine a precise value for k and to determine the effect the limiting growth factor will have on the accuracy of the model, future work will need to focus on how well the new model fits current data and for what bacteria growth rates the model holds true.

Another problem with the model exists within the parameter choices for the death rates of the blood and tissue neutrophils, d_1 and d_2 respectively. As previously explained, neutrophils in the tissue undergo chemical changes that allow them to live for several

days whereas neutrophils in the blood only live for 8 to 20 hours [3]. The current parameter choice of $d_1=d_2$ does not accurately represent the differences in the blood and tissue neutrophils' life spans. Changing the model by choosing death rates such that $d_1>d_2$ would more accurately reflect the biological nature of neutrophils. Future research is into the nature of neutrophils is necessary to determine accurate values for the separate death rates of blood and tissue neutrophils.

Further examination of equation (6) calls a different aspect of the model's biological nature into question. The killing term for the tissue neutrophils, z_1N_tB, allows for unbounded per capita phagocytic rates. This means as written, equation (6) allows for the possibility that a neutrophil can eat an infinite amount of bacteria. Research into the per capita phagocytic rate or killing rate of neutrophils has shown that a sigmoidal relation rather than linear relation exists between the per capita phagocytic rate of the neutrophils and the bacteria concentration [2]. As a result, the per capita phagocytic rate of neutrophils at first notably increases as the bacteria concentration increases and then begins to level off as the bacteria concentration continues to increase [2]. Thus the per capita phagocytic rate of neutrophils possesses a limit or a bound [2]. To accurately reflect the bound biology places on the neutrophil's per capita phagocytic rate, a limiting factor must be added to the killing term for tissue neutrophils in equation (6).

We propose a the following simplified model involving only bacteria and neutrophils that takes limited growth of bacteria and a bounded per capita phagocytic rate for neutrophils into account.

$$\frac{d}{dt}B = rB(1-B/K) - z\frac{B^m}{a^m+B^m}N_t \qquad (7)$$

$$\frac{d}{dt}N_b = s_1 + s_2\cdot\frac{B^{n_1}}{h_1+B^{n_1}} - d_1N_b - \frac{k_1B^{n_2}}{h_2+B^{n_2}}\cdot N_b \qquad (8)$$

$$\frac{d}{dt}N_t = \frac{k_1B^{n_2}}{h_2+B^{n_2}}\cdot N_b - d_2N_t. \qquad (9)$$

he differential equations for N_b and N_t are identical to equations (1) and (2). The ɔnstant z represents the maximum per capita phagocytic rate for tissue neutrophils ıd a is equal the bacterial concentration at which the phagocytic rate is half the ıaximum value. The upper limit for bacterial concentration is given by K. It is ıteresting to note that our model given by (7)-(9) yields bacterial concentrations (t) similar to the values obtained with the full model in equations (1)-(6). We ıoose parameter values for equations (7) and (8) as given in [7] and Appendix A. or equation (6) we let $K=10^9$ *c.f.u/ml* and estimated parameter values of $=1.14\times10^6$, $r=3.01$, $z=3.72$, and $m=1.20$ using a least squares fit to the ɔlution for the full model (1)-(6) derived by Takumi, Garssen, and others in [7].

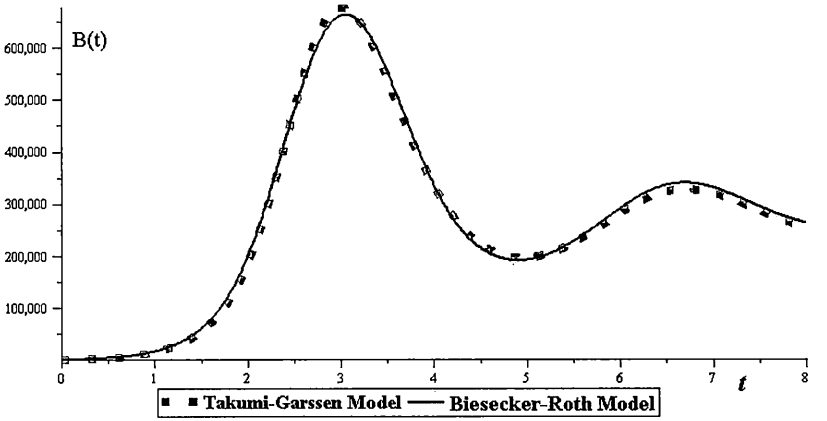

Figure 3. Numerical Solution of Equations (7)-(9)

Future work in this area could focus on determining an accurate bound for the per capita phagocytic rate of tissue neutrophils and calculating an accurate value for the constants a and m introduced in the limiting factor in equation (7). An investigation into the per capita phagocytic rates of the tissue and activated macrophages to determine whether or not introducing limiting factors is necessary could also be a focus of further research into this area. It would also be of interest to analyze the system of equations (7)-(9) to determine the number of equilibrium points and the stability of each equilibrium point.

BIBLIOGRAPHY

1. Bartle, R., D. Sherbert. Introduction to Real Analysis: Third Edition. New York: John Wiley & Sons, Inc., 2000.
2. Detilleux, J. "Neutrophils in the War Against Staphylococcus aureus: Predator-Prey Models to the Rescue." American Dairy Science Association 87 (2004):3716-3724.
3. Edwards, S. Biochemistry and Physiology of the Neutrophil. New York: Cambridge University Press, 1994.
4. Fagerström, T., P. Jagers, P. Schuster, E. Szathmary. "Biologists Put on Mathematical Glasses." Science 274 (1996): 2039-2049.
5. Nester, E., D. Anderson, C. Roberts, Jr., N. Pearsall, M. Nester, and D. Hurley. Microbiology: A Human Perspective. New York: McGraw Hill, 2004.
6. Roitt, I., P. Delves. Roitt's Essential Immunology. Oxford: Blackwell Science Ltd., 2001.
7. Takumi, K., J. Garssen, R. Jonge, W. Jong and A. Havelaar. "Release kinetics and cell trafficking in relation to bacterial growth explain the time course of blood neutrophils and monocytes during primary Salmonella infection." International Immunology 17 (2004): 85-93.

Appendix. Parameter Values from [7]

	Meaning	Value
r	Growth rate of bacteria	$3.1/day$
s_1	Rate of neutrophil release into blood (IOI)***	$1.6\times10^{6}\ cells/ml/day$
s_2	Max. rate of neutrophil release into blood during infection	$1.4\times10^{7}\ cells/ml/day$
s_3	Rate of monocyte release into blood (IOI)***	$3.0\times10^{5}\ cells/ml/day$
s_4	Max. rate of monocyte release into blood during infection	$8.0\times10^{5}\ cells/ml/day$
d_1	Neutrophil death rate in blood	$2.1/day$
d_2	Neutrophil death rate in tissue	$2.1/day$
d_3	Monocyte death rate in blood	$0.03/day$
d_4	Resting macrophage death rate in tissue	$0.03/day$
d_5	Activated macrophage death rate in tissue	$0.03/day$
k_1	Max. Neutro. migration rate from during infection	$1.1/day$
k_2	Monocyte migration rate from blood to tissue (IOI)***	$0.95/day$
k_3	Max. monocyte rate from blood to tissue due to infection	$1.7/day$
c	Activation rate of macrophages	$1.4\times10^{-9}\ c.f.u.^{**}/day$
z_1	Killing rate of neutrophils	$2.0\times10^{-6}\ ml/neut./day$
z_2	Killing rate of resting macrophages	$1.8\times10^{-9}\ ml/m\Phi^{*}/day$
z_3	Killing rate of activated macrophages	$8.6\times10^{-6}\ ml/m\Phi^{*}/day$
h_1	Constant for neutrophil release	2.1×10^{10}
h_2	Constant for neutrophil migration	6.0×10^{4}
h_3	Constant for monocyte release	3.2×10^{9}
h_4	Constant for monocyte migration	3000
n_1	Exponent for neutrophil release	1.9
n_2	Exponent for neutrophil migration	1.9
n_3	Exponent for monocyte release	2.0
n_4	Exponent for monocyte migration	1.1

*** (IOI) is an abbreviation for independent of infection.

** *c.f.u.*is an abbreviation for a colony forming unit.

* $m\Phi$ is an abbreviation for macrophage

The Effect of Parental Education on Emotions and Behaviors

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Department: Rural Sociology

ABSTRACT

Current literature suggests that emotions are learned through socialization. The following study was completed using results compiled by a survey done for the South Dakota State University (SDSU) Sociology of Rural America course (Soc 240). The authors wished to ask the question "Do the education levels of parents affect the emotions and behaviors of their children?" There were approximately 540 respondents to this survey, all college students at SDSU. Questions dealing with students' emotions were analyzed with respect to each respective student's parents' education level. The findings suggested that there is a connection between the parents' education levels and the emotions and behaviors of children.

INTRODUCTION

The primary focus of this research is to establish the significance of the parents' educational levels in regards to the emotional or social behavior of their child. The four primary variables which we restrict this study to are: comforting a friend, the feelings of depression and anger, and the behavior of crying. The study will do this with the following hypotheses:

1. People whose mother had some college education do not get angry very often.
2. People whose father had some college education do not get angry very often.
3. People whose mother had some college education do not feel depressed very often.
4. People whose father had some college education do not feel depressed very often.
5. People whose mother had some college education comfort a friend more often.
6. People whose father had some college education comfort a friend more often.
7. People whose mother had some college education cry less often.
8. People whose father had some college education cry less often.

METHODS

The survey used for this research contained a variety of questions, some relating to rural presumptions of the students and others relating to the emotions of the student and the emotions which the student perceived to be typical for each gender. The questions

with the most relevance to this study were those relating to the emotions of the student and the qualifying questions concerning the student's parents' education levels.

This survey was distributed by students in Soc 240, for the fall 2006 semester. Each student was asked to distribute five copies of the survey to their fellow students. A total of approximately 540 results were collected. Students distributed their surveys at places on the SDSU campus. After all information had been collected, Dr. Meredith Redlin, who taught Soc 240, compiled results for these variables using the Statistical Package for the Social Sciences (SPSS) software. The following hypotheses were tested with the use of a means test in SPSS.

HYPOTHESES

The question of "Do the education levels of parents affect the emotions and behaviors of their children?" was broken into eight different hypotheses, each pair relating to a question from the survey. In all of the hypotheses, the independent variable was the education level of the mother or the father.

The education levels of respondents' parents were uncovered through the use of questions 25 and 26 of the survey. Question 25 asked "What is the level of your father's education?" and asked respondents to rank this with: A) Not a high school graduate, B) High school graduate, C) Some college, D) Associate degree, and E) Bachelor degree or more. Question 26 asked "What is the level of your mother's education?" and used the same ranking system as before.

The first hypothesis, "People whose mother had some college education do not get angry very often." pertained to question 10 of the survey, which asked respondents "How often do you get angry?", as well as question 26, which dealt with the mother's education. The dependent variable for this hypothesis is the respondent's frequency of anger. Respondents were asked to quantify this on a scale of 1 to 5, with one being never and five being very often. The second hypothesis pertained to the same question as before, only now relating it to the education level of the respondent's father, question 25.

The third and fourth hypotheses are very much like the first and second, with the difference of dealing with how often respondents feel depressed. These two hypotheses deal with question 13 of the survey. This question asked "How often do you feel depressed?" and asked respondents to quantify this on a scale of 1 to 5. The scale was the same as that of question 10, with one being never and five being very often.

The fifth and sixth hypotheses relate to question 11 of the survey. This question asked "How often do you comfort or support a friend in need?" and used the same ranking scale as before.

The final hypotheses confronted, hypotheses number seven and eight, concerned question 9 of the survey, which read "How often do you cry?" and, once again, used the same ranking scale as all of the other questions.

DISCUSSION OF RESULTS

When reviewing the data for the first hypothesis, it can be found that those respondents whose mother had some college education reported being angry less often than those whose mother was a high school graduate. On the 1 to 5 scale, with one being never and five being very often, the mean scores for respondents were: 2.5127 for individuals whose mothers were not high school graduates, 3.0593 for individuals whose mothers were high school graduates, 2.8381 for those whose mothers had some college education, 2.7917 for those whose mothers had an Associates degree, and 2.7184 for those whose mothers had a Bachelors degree or higher. The average continues to decrease as the level of the mother's education increased (See Figure 1). The only inconsistency in regard to this set of data is that those respondents whose mother was not a high school graduate reported being less angry overall than those who had any higher education whatsoever. Perhaps those individuals whose mothers were not high school graduates were less quick to anger in general. Out of 540 respondents, only 23 reported having mothers who were not high school graduates. By comparison, all other education levels had over 100 respondents that qualified. To produce conclusive results, it might be better to survey more respondents that fit the category of having mothers who were not high school graduates. Overall though, the findings seem to suggest that there is indeed a connection between the level of education of the mother and her child's frequency of anger.

The level of the father's education seemed to have a slight effect on the frequency of his child's anger; the results, however, do not seem to be conclusive enough to suggest a connection. Those respondents whose father was not a high school graduate reported getting angry more often than all other education levels except that of "high school graduate (See Figure 1)." The mean score of these respondents (whose fathers were not high school graduates) was 2.913, while the mean score of respondents whose fathers were high school graduates was 2.9448 on the same 1 to 5 scale. There is a slight decrease in how often respondents got angry with the increase of education levels (2.8438 for those whose fathers had some college and 2.7286 for those whose fathers had an Associates degree) with the exception of "bachelor degree or more," in which the average score was 2.7937. As was previously stated, the evidence does not suggest any strong connection. There is a general decrease, but only interspersed with averages which do not follow the pattern. This may be due to the fact that the father is not generally considered to be the "primary nurturer." This might suggest that children are not exposed to their father and his emotions as much as those of their mother. Whatever the reason, the education level of the father in this instance does not affect the anger level of his children to the degree which that of the mother does.

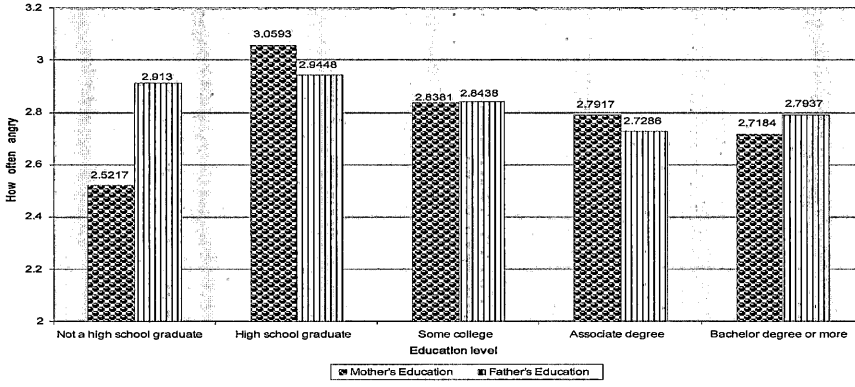

Figure 1. How often do you get angry?

The results related to the frequency of depression for respondents appear to show no consistent relation. For the father who was not a high school graduate, respondents reported feeling depression most often (2.4348 average score, once again with a score of one being never and five being very often), higher than any other education level, which is consistent with our hypothesis (See Figure 2). Education level increases after this category however do not seem to show any consistent decrease, with the average score for those whose fathers were high school graduates at 2.2966, the average for children of fathers with some college education at 2.3438, the average for children of fathers with an Associates degree at 2.3, and the average for children with Bachelors degrees or higher at 2.3085. Those respondents who had fathers who were high school graduates reported feeling depression least often, although those whose fathers had college degrees reported feeling depression at close to the same levels. The results related to the mother's education were even more inconclusive. Those respondents whose mothers had an associate degree felt depression the most often overall with an average score of 2.35, whereas those whose mothers were high school graduates reported feeling depression the least often overall with an average score of 2.2542 (See Figure 2). None of the other scores seemed to follow a pattern, with the average score for respondents whose mothers were not high school graduates being 2.3043, those whose mothers had some college scoring on average 2.3173, and those who reported their mother's education as being a Bachelors degree or higher scoring on average at 2.2989. Overall, it does not seem as if how often a person feels depression is linked to the education levels of that person's parents. This could be because depression apparently is not a learned emotion, but a psychological phenomenon.

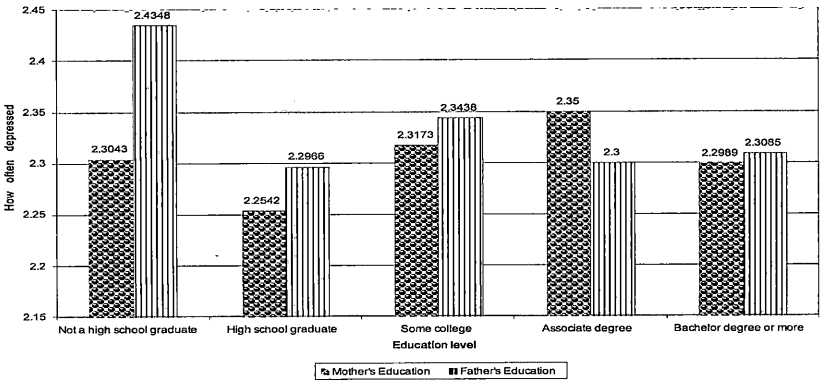

Figure 2. How often do you feel depressed?

The data collected concerning comforting or supporting a friend in need seems to be as predicted. As the education levels of both parents increase, the frequency with which respondents comfort or support a friend also shows a fairly steady increase (See Figure 3). Despite the fluctuations in levels of education such as "some college" for the mother (the frequency of comforting a friend suddenly jumps to an average score of 3.5619 and then decreases to an average score of 3.425, though continues to rise in relation to the previous levels, with an average score of 2.7291 being observed in students whose mothers were not high school graduates, rising to 3.3305 in those whose mothers were high school graduates, and finish the rise with an average score of 3.5485 in those whose mothers had a Bachelors degree or higher) and "associate degree" for the father (the same trend is observed, though not nearly as drastic, with average scores being: 2.6087 for students whose fathers were not high school graduates, 3.331 for those whose fathers were high school graduates, 3.4375 for those whose fathers had some college education, 3.4143 for those whose fathers had an Associates degree, and 3.5926 for those whose fathers had a Bachelors degree or higher, all of these scores use the same scale of ranking as before), the results suggest that the education levels of both the father and the mother are linked to how often the respondent comforts or supports a friend in need. Both parents' education levels seem to have an equal effect in this.

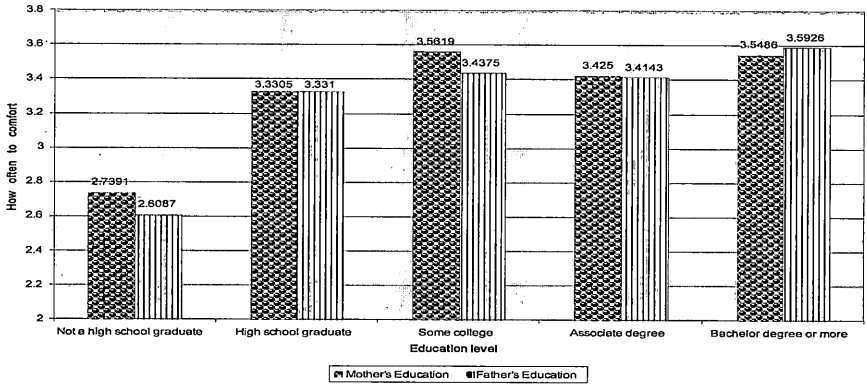

Figure 3. How often do you comfort or support a friend in need?

With the exception of the education level "not a high school graduate" for the father (with respondents ranking themselves on average at 2.4783, using the same scale as all of the previous questions), the frequency our respondents cry also seems linked to education levels. From the levels of "high school graduate" and on, there is a steady increase related to the father's education (See Figure 4). The average scores were 2.3793 for those whose fathers had graduated from high school, rising to 2.5 for those whose fathers had some college education, still rising to 2.5714 for those whose fathers had an Associates degree, and peaking at 2.6032 for those whose fathers had a Bachelors degree or higher. The education level of the mother also appears to cause a steady increase in how often respondents cry from the level of "not a high school graduate" with an average score of 2.1304, to "high school graduate" with an average score of 2.5424, and to "associate degree" with an average score of 2.5524 (See Figure 4). At "bachelor degree or more," a decrease was noted, with average scores dropping from 2.5583 for those whose mothers had an Associates degree to 2.4828. These results are opposite those which we hypothesized, but still suggest a connection. Also, the fact that the frequency with which the respondents cry increased with the education level of their parents may suggest that the more educated parents realize the need for a healthy outlet of emotions. These parents may encourage their children to express themselves more openly.

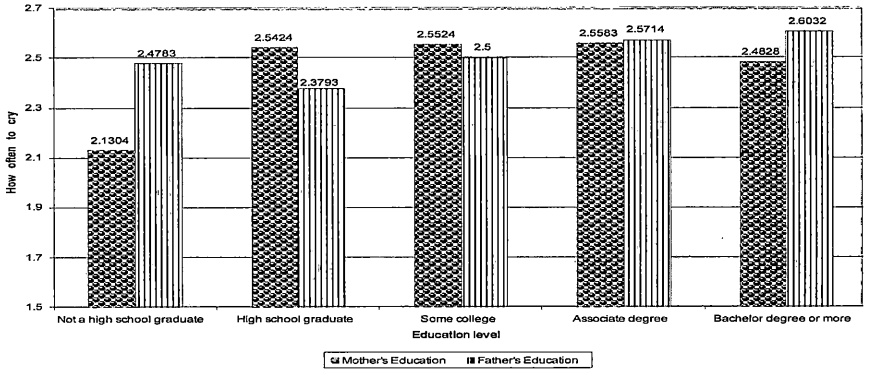

Figure 4. How often do you cry?

Overall, there seems to be a connection between the education level of the parents and certain emotions and behaviors of their children. The education level of the mother seems to have more influence in certain instances, reflecting the theory that the mother is the primary nurturer.

WHERE TO GO FROM HERE?

There is a definite link between a child's emotions and the education levels of that child's parents. But how much of a link is there? An obvious limitation to this study was that the survey used was not meant specifically for emotional research. Future research into this subject should consider a larger range of emotions and behaviors. Also, more of an unbiased sample should be selected, for instance, one with an equal composition of all education types. Students from more universities should also be included, and even society members of the same relative age range that aren't students. Using a sample of just college students gives the research a biased cast, as those whose parents have some form of higher education are more likely to pursue higher education themselves.

A possible experiment linked to this research would be one that follows a group of respondents. The respondents could be required to take a class on emotions and parenting, and then their children could later be surveyed to see if the class had any effect compared to the children of those respondents from the proposed control group who would not take this class. More research also needs to be done on the effects of the combined effects of the parents' education levels.

If the results prove to be conclusive, relating the education level of parents to the emotions of their children, this knowledge can be used to create some type of mandatory class for new parents of all areas. The class could contain instruction on emotional management, and could be implemented beginning in the eighth grade. This assures that those students not graduating high school will still have a more stable background to

instruct whatever offspring they might have on ways to handle their emotions, as well as which emotions are beneficial and should be promoted, and which are destructive and should be minimized or avoided altogether. This class or program could also be continued on to the college level, exposing students once again to this training.

ACKNOWLEDGEMENTS

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Theoretical Exploration of Characteristics of Up-conversion Materials in Photovoltaics

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ABSTRACT

Up-conversion materials can be used to greatly enhance the productivity of photovoltaic nanotechnologies. These materials must convert photons from a low energy to a higher energy to fit within the acceptable range of the solar panel. Software is needed to compute the value of these energy levels and to find molecules that produce these values. It must first be determined if the software has these capabilities and if the results are trustworthy. Naphthalamide has been a molecule of interest and serves as a good starting point for these studies.

Keywords: Photovoltaics, Up-conversion, Quantum mechanics

INTRODUCTION

Currently, the majority of the world's electricity is produced by combusting of fossil fuels. The most common downfalls of the production of energy from fossil fuels are the significant environmental implications. Also, fossil fuels are a limited resource which can not be depended upon perpetually. The centralized nature and transmission requirements of the raw fuels lead to large vulnerabilities for many nations (Foresman, 1996). On the contrary, sunlight is available across the globe without the environmental side effects and the need to transport the resource. Sunlight can be used indefinitely for harvesting. Yet, less than one percent of the United States' energy consumption comes from photovoltaic sources. The limited use of photovoltaics is due to its cost. Current photovoltaic processes, such as solar panels, are severely inefficient. Current solar cells only convert an average of thirteen percent of direct to usable energy (Owen, 2007). Only specific quantities of light are compatible with the receptor material on the solar cell. The rest of the light actually hinders the process by producing heat that interferes with the internal electrical components. To produce more electricity, the solar array must cover a larger area. More expansive panels are able to produce higher yields (nearly 18%), but at significantly higher cost. If an economical method to increase the efficiency of photo cells is developed, photovoltaics would become feasible (US DoE, 2006).

One of the most promising areas in this field of study involves the up-conversion process. Up-conversion would not produce electricity, but convert photons from a low

energy to a higher energy to fit within the acceptable range of the solar panel in achieving a higher efficiency (Solar Electric Power Association, 2006).

PHOTON ABSORPTION AND EMISSION

To understand the shortcomings of photovoltaics and the opportunities that an up-converter can offer, a basic understanding of light and basic chemistry itself must first exist. Visible light has the characteristics of both waves and particles. The wave-particle theories are complex and involved, but a simplification is to picture light as small particles - called photons - traveling forward in an oscillating motion. The bobbing motion of each photon creates a perfect wave pattern (Atkins, P.W., 2002). As light moves from one point to the next, it travels at a constant speed, approximately 300,000 kilometers per second. Every photon travels at this same speed, but not photons move in the same wave motion. The range of wavelengths that light produces causes the different colors of the rainbow, but also produces different levels of energy (Kobes, et al, 2004). The amount of energy is inversely proportional to the wavelength of the photon (or directly proportional to the frequency of the photon). That means that a photon with a short wavelength has a high energy value. Three photons of different wavelengths travel from A to B as shown in Figure 1. It can be seen that the shorter wavelength photon has to cover more actual distance between the two points. The photon contains more energy because of the additional movement. This concept is essential for the development of up-conversion materials.

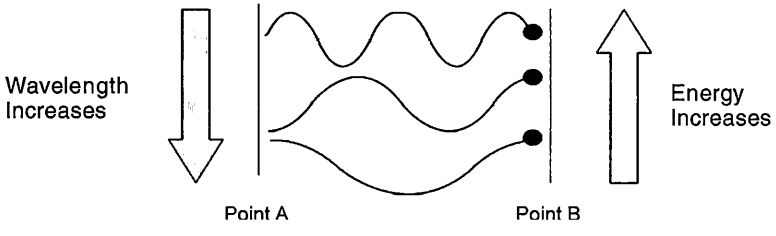


Figure 1. Wavelength and energy

All matter is composed at the nanoscale of atoms. Atoms are composed of protons, neutrons, and electrons. The electrons around the nucleus of any atom have exact orbital levels where they can travel. What defines these orbitals is the energy of the electron. An electron in each of these orbitals then has a specific energy value corresponding to the distance the orbital is from the nucleus. Electrons farther from the nucleus have more energy. An electron's natural orbital is referred to as its ground orbital, and this electron is a ground state electron. Electrons will leave their orbital if the amount of energy it contains changes. Electrons may absorb or emit energy. Occasionally, an electron will gain a specific amount of energy that will make it migrate to a higher orbital where the new energy level is compatible. This electron is an excited electron in an excited state. An

excited electron is highly unstable and immediately returns to its ground state orbital. The electron uses very little energy to move back down to its ground state orbital. To be accepted back in, it must release the rest of the excess energy it absorbed. The electron simply shoots this energy out. The energy it shoots out is a newly created photon. This photon has a wavelength that correlates to the amount of the energy provided by the electron (Paschotta, 2006).

This process can begin when a photon collides with an electron. The photon is destroyed and the electron gains all the energy, moves to an excited state, and then emits energy back out as it returns to ground state. The photon that was destroyed has nearly the same energy as the one created. Figure 2 illustrates this cycle.

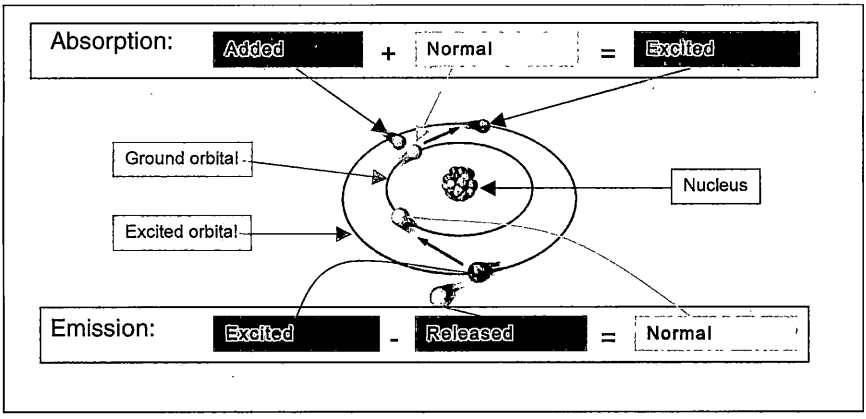


Figure 2. Photon absorption and emission

TWO-PHOTON UP-CONVERSION

Up-conversion is based upon the concept of photon absorption and emission. An electron is very uncomfortable outside of its ground state and is excited for less than a fraction of a second. The process is virtually instantaneous. Occasionally, though, this process is interrupted and two-photon absorption occurs. At the one brief moment an electron exists at the excited state, a second photon collides with the excited electron. This second photon is destroyed and the energy is added to the electron. The electron then moves up to yet another orbital. The irate electron immediately releases all of its energy and retreats all the way back to its ground state orbital. All the energy expelled from the electron creates a new photon. This single photon has roughly the sum of the energies of the two absorbed photons. The photon now has a very short wavelength and very high energy. Two-photon absorption has occurred (Foresman, 1996). Therefore, in this case, up-conversion is accomplished via two-photon absorption. The up-conversion process takes two low energy photons and converts them to a single, high-energy photon as shown in Figure 3.

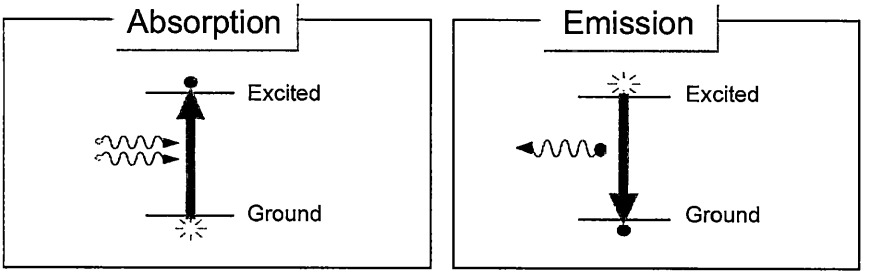


Figure 3. Up-conversion process

As stated earlier, solar panels are very inefficient. Only a small range of photons within visible light have the correct energy level and wavelength to interact with the electrons in the solar panel to produce electricity. Some photons have too much energy while many others do not have enough as seen in Figure 4.

Up-conversion can assist by converting low energy photons into higher energy photons that would be compatible with the solar panel. Materials can be analyzed to determine the energy value required to excite the electrons within its atoms to a first or second excited state orbital. If the value for the second state orbital is determined to be equivalent to the energy of the photon acceptable by the solar cell, the material can be used in the up-conversion process. A thin film of the material spread across the face of the solar panel would ideally allow the appropriate photons to pass through while using creating additional photons for the solar panel, as shown in Figure 5.

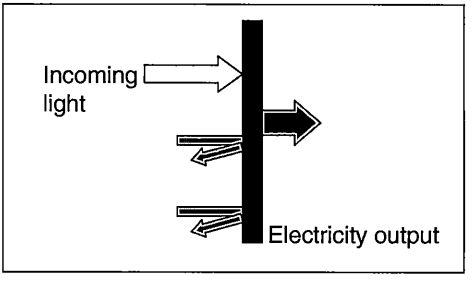


Figure 4. Solar panel without up-converter

The solar panel itself would not need to be altered. It would only need to absorb the small range of photons as before. The up-conversion material would provide the solar panel with more photons within this range. More photons would produce more electricity per each solar panel. More electricity would increase the electrical output. A higher output means higher efficiency. Greater efficiency cuts back the price of production.

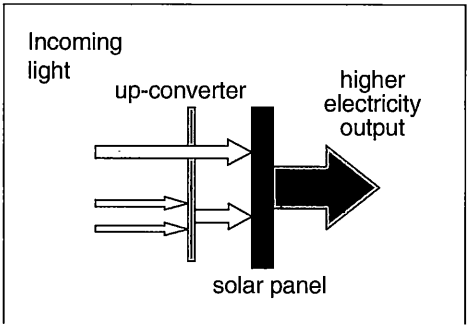


Figure 5. Solar panel with up-converter

IDENTIFYING AN UP-CONVERSION MATERIAL

To be able to develop an up-converter, data must first be collected about the material used. A material must be analyzed at the molecular level to determine if it is suitable to be used as an up-converter. Over the past decades scientists have made large advances in the concepts and understanding of the molecular behavior (Giordano, 1997).

Determining the energy needed to move an electron away from the nucleus is quite difficult to determine in a laboratory environment. Quantum mechanical equations can be used instead. Schrödinger's equation can be used to define for the energy of particles in a quantum system. This equation is so complex that it can only be used to solve the most trivial systems. These systems are far simpler than any material that would be a suitable up-converter. Many numerical methods have been developed to find approximations to Schrödinger's equation. Three popular types of methods are semi-empirical, electron correlation, and post-SCF. Each contains many different sub-methods. As the methods become more complex, they become more accurate. These approximations have advanced to the point where they are able to predict the properties of large molecular systems. Such a vast number of calculations are required that a computer is needed to solve them. Various forms of statistics, algebra, and calculus are combined within each of the separate methods.

Using the quantum mechanical methods, a material can be analyzed on the molecular level. Within the data analyzed, it may be possible to identify the up-conversion process. The path to take through the quantum mechanical methods must first be carefully mapped. Basis sets are the first step to approximating solutions to the quantum mechanic equations. Basis sets are groups of equations utilized to define all the possible orbitals that could exist for each molecule in the material or system. Quantum mechanical experts have created specific basis sets to fulfill the needs of many systems. Some of the more common basis sets are named STO-3G, 3-21G, 6-31G, and 6-311G. Basis sets may be modified to cover a specific material. As with the quantum methods, the more complex the basis set, the more accurate its results.

A model chemistry is the addition of one basis set to one method of approximating Schrödinger's equation with. As a model chemistry gets more complex, the results tend to create a more accurate solution. Unfortunately this is not always true. Model chemistries must be chosen to match certain characteristics of the system of interest. Occasionally the most accurate results are found from the most basic model chemistry. Choosing the most appropriate model chemistry often requires several tests and a large amount of patience. More time spent researching and testing during this first step eliminates severe errors in computation throughout the remaining steps (Güdel, 1998).

SOLVING THE MODEL CHEMISTRIES

Model chemistries provide a way to solve Schrödinger's equation and evaluate a molecule. The amount of computations required to solve the equations within the simplest model chemistry is daunting. Using a computer is the only realistic way to solve a model chemistry. Gaussian is an impressive software system that solves model

chemistries with vast capabilities, but locating results in the output requires focused input procedures (Frisch, 2005). An important decision is determining the appropriate model chemistry that Gaussian is to use. Information verified in a laboratory setting must be compared with the results found by different Gaussian tests. Numerous model chemistries must be tested on one material to determine which method is most accurate.
Several low level calculations can be compared for numerous organic molecules with satisfactory accuracy. Gaussian can be programmed to return a variety of results. Conveniently the most frequently used application of Gaussian is to calculate the energy of a system's particles. For the energy calculations to be accurate, the structure of the molecule must be correct and the frequencies must be inspected to verify a stable structure, which requires three separate Gaussian routines. Table 1 shows different organic molecules and the model chemistry which found the most accurate energy after running the three jobs. It can be seen that Gaussian can return accurate results.

Molecule	Experiment (cm^{-1})	Gaussian deviation (cm^{-1})	Model chemistry used
CH	1,429	+12	MP2FC/6-31+G**
Benzene	21,393	+53	BLYP/cc-pVDZ
Acetone	17,775	+7	MP2FU/6-31G*
Butane	27,885	-2	B3LYP/6-31+G**
Propene	16,857	-5	HF/6-31G*
Ethylene	10,797	-1	B3LYP/6-31G*
Cyclobutene	18,500	-22	AM1[a]
Formaldehyde	5,644	+1	B3LYP/6-31+G**
Formamide	9,688	+1	QCISD/6-311G**

Table 1. Verifying Gaussian's accuracy

Users first define the structure of the molecules involved. Then model chemistry and basis set must be selected and tested. The user then defines whether the system is in a gas or liquid phase. Once these original parameters are established, Gaussian is programmed with the correct keywords and commands to produce relevant data. Gaussian then uses the equations developed within each method and basis set provided to converge on the most probable solution to Schrödinger's equation for the given system.

Figure 6 shows some preliminary data and the model of the atom returned using the OPT command for optimized geometry including bond lengths, bond angles, dihedral angles, dipole moments, Milliken charges, coordinates, etc. Figure 7 shows the data returned using The FREQ & ENERGY commands including energy of structure, frequencies/intensities of spectral lines, displacement of nuclei, thermochemistry, polarizability, nature of minimums, etc. Figure 8 shows data returned CIS commands including all virtual and occupied orbitals, orbirals and kinetic energies, orbital symmetries, etc.

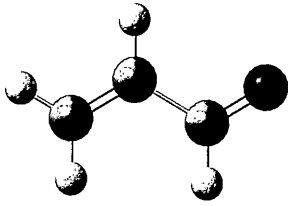


Figure 6. OPT Command for optimized geometry.

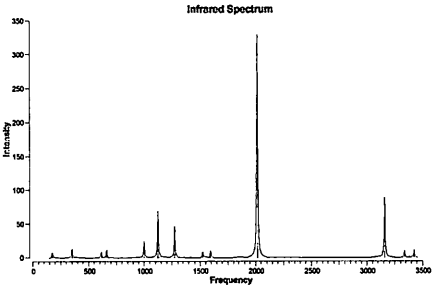


Figure 7. FREQ & ENERGY Commands for frequency and energy.

UTILIZING GAUSSIAN TO IDENTITY UP-CONVERSION

Gaussian possesses a tremendous list of commands and functions with a myriad of purposes. Extensive research and testing of the software did not yield a direct command or string of commands to identify two-photon absorption within a molecular system. Different theories can be applied to the Gaussian software to see if the data contains proof of two-photon absorption.

Theory 1

For two-photon absorption to occur, it is necessary for an electron to absorb a photon, become excited, and then absorb a second photon before emitting the energy of the first photon. An electron will not hold the energy of the first photon for more than a fraction of a second, so the second photon needs to strike the electron almost instantaneously. A short delay after the first photon is absorbed would assist in achieving two-photon absorption. Hypothetically, the energy absorbed by the electron from the first photon can cause the molecule to physically change its structure. The structural change of the molecule could allow enough time for a second photon to be absorbed by the electron. It is possible that this delay would allow time for two-photon absorption (Güdel, 1998). When a molecule changes shape the energy of the system changes. Gaussian can track a change of energy within a system for a discrete number of steps. If Gaussian is provided with an initial structure, final structure, model chemistry, and the appropriate keywords, it will produce results that can be interpreted, manipulated, and graphed on a energy versus time plot as seen in Figure 9.

A valley on the graph is called a stationary point. The beginning structure and ending structure are two stationary points. Other existing stationary points on the graph are called a transition structure. A transition structure exists where the structure held a shape for a prolonged period of time before further changes continued. It is at these points that two-photon absorption may be possible.

In laboratory testing, Gaussian was provided with the ground state structure and the excited state structure of molecules that are known to possess two-photon absorption

capabilities. Unfortunately, Gaussian did not return the necessary data. This may signify that the molecules investigated did not change structure between excitation and relaxation. This may also signify that the structure did change, but without passing any transition structures. Since no results were returned, this theory was no longer pursued to identify two-photon absorption.

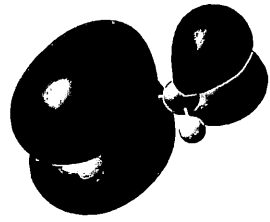


Figure 8. CIS Commands for highest occupied molecular orbitals (HOMO).

Theory 2

The energy difference between each of the orbitals of a system of molecules can be computed in Gaussian in several different ways. The difference in energy between a ground state orbital and an excited state orbital is equivalent to the energy of the photon absorbed. In a physical laboratory, the material can be exposed to light and the emission and absorption spectra can be examined. From these spectrums, the energy of the photons absorbed can be determined. If the results of Gaussian job matches the physical tests, Gaussian's results are verified.

On the other hand, if the results of Gaussian's test job were significantly higher (nearly double) of the physical lab tests it could be the effect of two-photon absorption. Long wavelength photons have less energy then short wavelength photons. If a molecule needs a photon with a wavelength of 300 nm to reach the first excited state, but is absorbing photons of 600nm, it would require exactly two photons to achieve excitation. The process that occurs in this instance is up-conversion.

In one set of test runs on a viable molecule, Gaussian predicted absorption at 286nm. Spectral tests showed photons of 486nm being absorbed. These results suggest up-conversion took place. Research determined that the spectral tests were conducted with the molecule submerged in a solvent. The solvent may have caused the change in absorption. Gaussian was not able to return similar results when a solvent was added to the computations. Data was not available for spectral tests on the molecules not submerged in the solvent. The second theory may have potential, but has not yet been able to identify two-photon absorption.

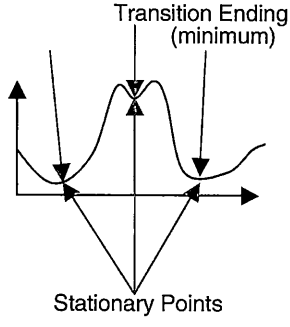


Figure 9. Energy vs. time graph

Theory 3

Naphthalamide is a molecule with many interesting characteristics. Naphthalamide has been known to perform up-conversion. A greater understanding of this molecule and why it undergoes the up-conversion process can lead to ways of recreating the process. Unfortunately, the different forms of naphthalamide are large and require extensive computation time to be analyzed. Several derivatives were modeled and used in the tests previously mentioned (Tian, et al, 1998).

The structure of three naphthalamide forms as shown in Figure 10. Figure 11 shows some of the characteristics of the derivative 4-amino-1,8-napthalamide.

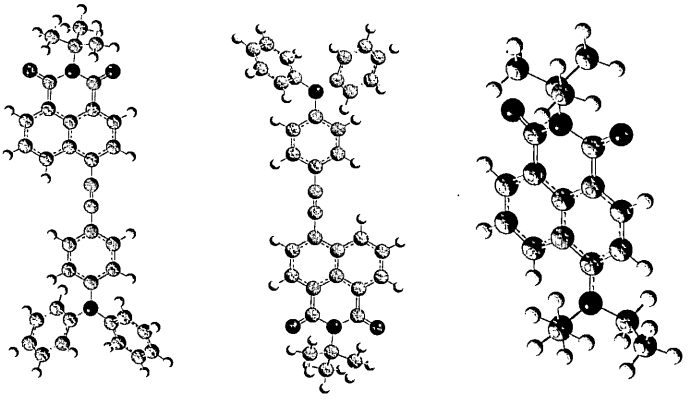
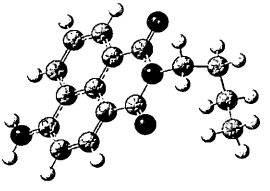
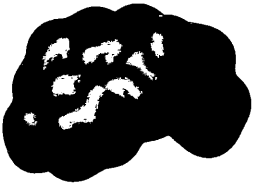


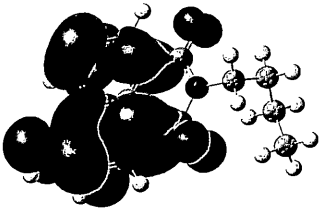
Figure 10. Forms of naphthalamide



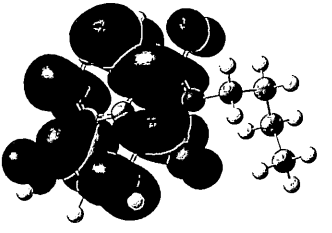
(a) Optimized geometry



(b) Electron density surface



(c) Highest occupied molecular orbital (HOMO)



(d) Lowest unoccupied molecular orbital (LUMO)

Figure 11. Characteristics of naphthalamide derivative

Finding information about the forms of naphthalamide is difficult as few laboratory tests have been performed on the complex molecules. It takes many hours to verify the correct structure and orbitals of the different forms of naphthalamide with Gaussian. When model chemistries were selected to begin running tests on the simplest naphthalamide forms, it was quickly determined that a computer system was not available to handle the vast number of computations. This theory cannot be pursued until larger computer systems are available.

DISCUSSION AND CONCLUSIONS

For an up-conversion material to be utilized within a photovoltaic system, one must first be identified. To simply see the process of two-photon absorption occur in a laboratory setting is insufficient information to develop an up-converter. The complex process must be understood to create a desirable material.

A molecule must undergo significant two photon absorption to be considered for use as an up-converter. Current molecules must be exposed to a very high intensity of specific wavelengths of light for this to occur. This intensity would never occur naturally. Most of the laboratory test results available for two photon absorption were achieved using lasers. Even when using a laser under prime conditions, very few up-converter photons were created. The ability to construct a up-converter that will return significant viable photons relies on a larger understanding of the process.

Several possibilities exist that may significantly open the road for future study. Running an absorption spectrum test on naphthalamide with parameters that can be duplicated in Gaussian would open a path for discovery. The Gaussian results could then be verified, the most exact model chemistry could be located, and further jobs could be conducted with a much higher platform to start from starting at a much higher platform. Less computations would be needed. Faster computers would allow larger molecules to be modeled and studied.

At the completion of this study, a concrete solution to the up-conversion problem has yet to be identified. Further testing with Gaussian is needed before it can be either ruled in or out as a method of studying two-photon absorption within molecular systems.

ACKNOWLEDGEMENTS

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REFERENCES

Atkins, P.W., 2002, Chemical Principles: The Quest for Insight, WH Freeman and Company, New York, NY, pp. 1-40, Ch 1.

Energy Information Administration, 2006, "Renewable Energy," Official Energy Statistics From the U.S. Government, www.eia.doe.gov

Foresman, J. B., and Frish, A., 1996, Exploring Chemistry with Electronic Structure Methods, Gaussian, Inc., Pittsburgh, PA,, pp93-160.

Fowler, M., 2006, "The Speed of Light," UVA Physics Department, http://galileo.phys.virginia.edu/classes.html

Frisch A., Frisch M., Trucks G., 2005, Gaussian 03 User--s Reference, Carnegie, PA, Gaussian, Inc, 2nd ed., 2005, pp 22-28.

Giordano N.J., Computational Physics, 1997, Prentice Hall, Upper Saddle River, pp. 245-300.

Güdel H.U., New Light-Emitting Inorganic Materials, 1998, Chimia, pp. 561-565.

Kobes, A, and Kunstatter, G., 2004, "Properties of Waves," Physics Department University of Winnipeg website, http://theory.uwinnipeg.ca/mod_tech/node120.html

Owen, G., "Solar Technology Efficiencies Today?" 2007, http://www.solareexpert.com

Paschotta, R., 2006, "Excite State Absorption," RP photonics website, http://www.rp-photonics.com/excited_state_absorption.html

Solar Electric Power Association, 2006, "PV Basics: PV Facts Sheet," www.solarelectricpower.org

Tian H., Xu T. , Zhao Y., Chen K., 1998 "Two-Path Photo-Induced Electron Transfer in Naphthalamide-Based Model Compound", Institute of Fine Chemicals, East China University of Science & Technology, Shanghai, China.

US Department of Energy , 2006 "Solar Energy Basics"www.eere.energy.gov.