

# MCNAIR SCHOLARS RESEARCH JOURNAL 2015





### A MESSAGE FROM THE WSU MCNAIR SCHOLARS PROGRAM

The Ronald E. McNair Postbaccalaureate Achievement Program is one of eight Federal TRIO educational access and equity initiatives. The Wayne State University McNair Scholars program is funded by a \$1,125,000 grant from the U.S. Department of Education, Office of Postsecondary Education.

The McNair Scholars program is designed to prepare the next generation of scholars, professionals and leaders for doctoral study in the nation's top research universities. The purpose of the program is to increase the number of academically talented persons from low income/first generation and or underrepresented backgrounds with an earned Ph.D. McNair Scholars programs currently exist at over 200 colleges and universities.

The McNair Scholars program attracts applications from a highly competitive pool of undergraduate students with strong interest in research and graduate studies. Throughout the program year, McNair Scholars begin preparing for graduate school, receive research training and instruction and develop research proposals. The experiences prepare students for the Summer Research Experience where students conduct research projects under the guidance and mentorship of a faculty member. Scholars also complete an intensive research course, obtain GRE test preparation and engage in professional development workshops.

McNair Scholars present their research at the WSU Undergraduate Research Conference and select National McNair Conferences held throughout the nation.

The 2015 edition of the Wayne State University McNair Scholars Research Journal highlights the accomplishments of our Scholars and reflects the work of a wide variety of academic disciplines.

Please join the McNair Staff in congratulating the Scholars on their contributions to the advancement of knowledge in their respective fields of interest.

GO WARRIORS!!!!!

The Wayne State University McNair Scholars Staff

### TABLE OF CONTENTS

McNair Program Staff	4
Micro-cracking and its Effects on Formability in Advanced High Strength Steels (AHSS) Olamide Alabi, Wayne State University	5
Xin Wu, PhD, Department of Mechanical Engineering, Wayne State University	
Lanthanide based water-tolerant asymmetric catalysis of the Michael reaction Joshua L. Fischer, Wayne State University	12
Matthew Allen, PhD, Department of Chemistry, Wayne State University	
Modeling Posttraumatic Stress Disorder and its Treatments Donovan Garmo, Wayne State University	22
Shane Perrine, PhD, Department of Psychiatry & Behavioral Neurosciences	
For the Betterment of the Race: The Efforts of the Detroit Urban League in Assimilating Blacks During the Early Great Migration, 1916-1917 Andre Gilford, Jr., Wayne State University	29
David Goldberg, PhD, Department of Africana Studies	
<b>The benefits of Plug -In – Hybrid and Electric vehicles on the Economy and the environment</b> Gregory Gillette, Wayne State University	36
Yeau-Jian Liao, PhD, Engineering Technology Division, College of Engineering	
An Improvement to the Standard Micro Pillar Design to Quantify Contraction Forces Produced by Cardiac Myocytes Ahmedul Islam, Wayne State University Ming-Cheng Cheng PhD Department of Electrical & Computer Engineering	45
Thing cheng cheng, The, Department of Licenteal & compater Engineering	
Arduino: Banking System Prototype Kayla Jordan, Wayne State University Umer Khalid, PhD Candidate, Department of Electrical Engineering	50
Relationship between Psychological Distress and Inflammation in Pregnant African American Women Maricruz Moya, Wayne State University	57
Carmen Giurgescu, PhD, College of Nursing	
Vehicle-To-Vehicle Communications a Software Approach to Develop Cluster Based DSRC Safety Messages	66
Jason Shepherd, Wayne State University Ece Yaprak, PhD, Engineering Technology Division, College of Engineering	
<b>Comparison of R Implemented Topology-based Pathway Analysis Tools using Target Pathways</b> Alyssa Wilkins, Wayne State University Sorin Draghici, PhD, Department of Computer Science	73

**Enhancing Liquid Lens Using Electrowetting and Graphene Material** Camille Williams, Wayne State University Ming-Cheng Cheng, PhD, Department of Electrical & Computer Engineering

## MCNAIR PROGRAM STAFF

Henry L. Robinson Director Office of Federal TRIO-McNair Scholars Co-Principal Investigator

Dr. Joseph Dunbar, Ph.D Associate Vice President for Research/Graduate School Co-Principal Investigator

> Allanté Whitmore McNair Scholars Program Supervisor

> > Carolyn Porter Counselor

Marie Elena Villanueva Administrative Assistant

## MICRO-CRACKING AND ITS EFFECTS ON FORMABILITY Advanced High Stress Steels (AHHS)

#### By Olamide Alabi Major: Chemical Engineering Mentor: Dr. Xin Wu, Department of Mechanical Engineering

#### ABSTRACT

Advanced high strength steels (AHSS), such as dual phase (DP) steels, improve safety and fuel efficiency in the auto industry, but this class of steel is subject to micro-cracking. Understanding the unpredictable micro-cracking will help develop engineering designs to reduce micro-cracking (Demeri, 2013; Wu, Bahmanpour, & Schmid, 2012). The purpose of this study is to characterize micro-cracking and study the deformation caused by the edge-shearing of DP steels. A tensile test with digital image correlation provided information on material properties, a 3D scanner measured the topological characteristic of the shared edge, and scanning electron microscopy (SEM) further aided in characterizing mirco-cracks and correlating formability. This study examines the mechanical properties of DP 600 and plans to identify a correlation between shearing and formability. The results of the study will provide more literature on mirco-cracking in AHSS to relate to the issue of micro-cracking during auto body part processing.

Keywords: Advance high strength steels (AHSS), dual phase (DP) steels, micro-cracking, and formability

Using lightweight advanced high strength steels (AHSS) in auto body parts is environmentally friendly. Reducing only 10% of an automobile's weight can reduce gasoline consumption by 3% to 7% (Xiaodong, Zhaohui, & Li, 2005). Although AHSS are lighter than traditional steel, this advance class of steel is much stronger than traditional steel and increases crashworthiness of automobiles (Evin, Tomas, Katalinic, Wessely, & Kmec, 2013). Dual phase (DP) steels are a type of AHSS that is highly abundant in varying tensile strengths compared to other AHSS (Xiaodong et al., 2005). Kuziak, Kawalla, and Waengler (2008) noted that DP 350/600 steels are used in the ancillary parts, body structure, closures, suspension or chassis, and wheels of a car. Unfortunately, AHSS are subject to unpredictable micro-cracking that can start during sheet metal forming and the processing of the auto body parts. Micro-cracks are unpredictable fractures that occur at the microstructure level of a material (Wu et al., 2012).

Current research in AHSS focuses on identifying material properties and understanding micro-cracking to eventually develop solutions for the micro-cracking problem. According to Kolbasnikov, Bezobrazov, and Naumov (2013), the auto industry uses DP steels in the cold stamping of auto parts for its high strength and good formability. Formability is the ability of a material to withstand deformation before permanently, or plastically, deforming. Past research in DP steels focuses on its properties and formability (Avramovic-Cingara, Ososkov, Jain, & Wilkinson, 2009; Kadkhodapour, Butz, Ziaei-Rad, & Schmauder, 2011). Research on the micro-cracking caused by shearing of DP steels only characterizes the micro-cracking on the sheared edged without examining the effects of formability from the micro-cracking (Wu et al., 2012).

#### **RESEARCH QUESTIONS**

This study aims to examine the mechanical properties of DP 600 and identify a correlation between microcracking and formability. The purpose of this experimental study is to understand micro-cracking caused by shearing in dual phase steels and relate shearing to formability. The central research question is how does microcracking affect AHSS. The study's results will provide answers to the following questions:

1. What is the micro-crack characterization on the sheared edge of dual phase steel?

2. What is the correlation between micro-cracking caused by shearing and formability?

From the micrographs of the sheared samples, the micro-cracks are examined. The relationship of microcracking with formability will be gathered from the results of in-situ tensile testing that uses an imaging technique.

The literature review provides background information on dual phase steels and micro-cracking research. Following the literature review, the methods will include the theoretical framework and experimental procedures. Finally, I will provide the results, discussions, and conclusions of this research.

#### LITERATURE REVIEW

The auto industry is an important market for AHSS because auto body structures require the properties of the material to meet current environmental and safety regulations (Demeri, 2013). Because AHSS is subject to unpredictable micro-cracking, research with AHSS focuses on identifying material properties and understanding micro-cracking to support the auto industry. The background research includes: (1) the benefits of AHSS for the auto industry, (2) the microstructure and properties of DP steels, and (3) micro-cracking and deformation in DP steels.

#### BENEFITS OF AHSS

To meet the new emission standards and fuel efficiency mandates brought on by environmental consciousness in twenty-first century, automakers must use AHSS in auto body structures (Demeri, 2013). Xiaodong et al. (2005) explained that reducing the weight of vehicles is the most effective way to reducing emission and gas consumption. AHSS are lightweight and some types are very ductile to form into automobile parts. According to Evin et al. (2013), incorporating lightweight steel in the auto body structure reduced the auto body weight by about 30 to 40%.

Although the auto industry must use lighter steel to reduce the weight of the car for environmental reasons, the steel must be stronger and the design of vehicles must be safer to increase passenger safety. Liewald and Radonjic (2014) discussed the use of different types of steels in auto body components to increase safety. Some parts of a vehicle contain conventional high strength steels that are easier to form into auto parts than AHSS, whereas automakers use AHSS for the inner beams, main floor, and roof compartments.

#### PROPERTIES OF DP STEELS

AHSS are stronger than traditional high strength steels because they are hardened by phase transformations at the microstructure level. Precipitation, grain refining, and solid solution harden conventional high strength steels. A phase is a homogeneous portion of a substance that has uniform physical and chemical characteristics. The steel makers classify AHSS by their steel phases. For example, DP steels with a low yield ratio and work hardening ratio contain the ferrite and martensite phases of steel. A matrix of the ferrite phase surrounds

particles of the martensite phase, and the particles usually consist between 5 and 20% of the DP steel microstructure. AHSS types are also subject to different types of processing, such as hot-rolling, cold-rolling, and hot dip galvanized, that also affect properties within the steel such as alloy content, weldability, and mechanical properties (Xiaodong et al., 2005). This study uses cold-rolled DP steel. Of the various types of AHSS, DP steel is the most common in auto body structures and is the focus of many researches including this study (Kuziak et al., 2008).

The auto industry uses DP steels in the cold stamping of auto parts for its high strength and good formability (Kolbasnikov et al., 2013). In addition, DP steels are more abundant in varying tensile strength than other types of AHSS (Xiaodong et al., 2005). According to Avramovic-Cingara et al. (2009), DP steels can contain additional phases such as small amounts of bainite and retained austenite. The volume fraction of martensite controls the material properties of DP steel as increasing the amount of martensite decreases the material's ductility. Wu et al. (2012) noted that yield strength and ultimate tensile strength increases with an increase in martensite volume. Likewise, Kuziak et al. (2008), identify the amount of martensite as characterizing the strength of DP steel, and the size and distribution of the martensite particles as characterizing the ductility of DP steel. The optimum properties of DP steel are acquired at approximately a 20% volume fraction of the martensite phase. Fine nano-sized particles of martensite dispersed in the ferrite phase of steel create a better combination of strength and ductility in DP steels, whereas the ferrite in a coarse martensite structure will develop cleavage fractures (Avramovic-Cingara et al., 2009). DP steels with a martensite volume fraction over 20% are referred to as partial martesite steel (Kuziak et al., 2008; Xiaodong et al., 2005).

#### MICRO-CRACKING AND DEFORMATION IN DP STEEL

While processing the material, AHSS is susceptible to edge and interior cracking that starts at the microstructure level. Characterizing the micro-cracks and quantitatively measuring the severity of the micro-damage will aid in solving the cracking problem. Wu et al. (2012) developed a standard experimental procedure to characterize the sheared edges prior to stamping operation for DP steel with strengths of 600, 780, and 980. The researchers used the results of a tensile test to create true stress and true strain curves to determine the plasticity of the different DP steel strengths. Shearing tests were conducted at four different die clearances. Digital imaging correlation (DIC) pictures the material and the strain during deformation measured over the entire area under test. Traditional DIC imaging and software package pricing start over \$60,000 and can go over \$100,000 (Kuykendall, 2013). This project introduces a more cost effective optical imaging system that incorporates a simple camera with its own lighting that costs less than \$100.

However, a research gap exists in micro-damage caused by edge-shearing. In addition, the correlation between the damage from processing to sheet metal stamping requires more research to improve the understanding of AHSS edge cracking. The internal damage caused by micro cracking will affect the formability of AHSS and cause the material to withstand less plastic deformation (Wu et al., 2012). Kadkhodapour et al. (2011) and Ghadbeigi, Pinna, Celotto, and Yates (2010) examined the formability of DP steels with in-situ tensile testing and found that the ferrite phase and martensite phase deform at different rates. Ferrite grains or particles deform immediately at a high rate, and the martensite particles may not deform or have delayed deformation at a much slower rate than the ferrite grains. Wu et al. (2012) also examined the edge topology of dual phase steels to obtain mean values for edge zone heights using a replica method that did not clearly set the top surface position. Similarly, this study examines the edge topology of the actual mechanically sheared blank with 3D laser scanning microscopy and correlates the surface roughness to formability.

#### SIGNIFICANCE

AHSS are essential to the auto industry to address the environmental and safety issues of automobiles. Understanding the micro-cracking in DP steels will aid in finding solutions to the micro-cracking problem. Mirco-cracking will affect the formability of AHSS, so examining the relationship between micro-cracking and formability is necessary. The martensite distribution and volume fraction affects the formability of dual phase

steels (Kadkhodapour et al., 2011). Wu et al. (2012) also indicated a need for the characterization of edgecracking prior to shearing.

#### METHODS

This study expands on the edge fracture study of Wu et al. (2012) and introduces effective and low cost imaging techniques using DIC to examine the properties of DP 600. DP 600 is not as strong as DP 980 and is easier to shape and manipulate. In addition, the method used by Kadkhodapour et al. (2011) and Ghadbeigi et al. (2010) to examine formability provides precedence for the correlation of micro-cracking and formability. The methods such as SEM and tensile testing with DIC in these prior studies set the theoretical framework for this study. Wu et al. (2012) used SEM to observe the morphology of the specimens and optical microcopy to measure the edge zone strain. Kadkhodapour et al. (2011) used tensile testing to investigate the mechanical properties of dual phase steels, specifically DP 800. Ghadbeigi et al. (2010) used in-situ tensile testing with DIC incorporating a scanning electron microscope to evaluate formability in DP 1000.

#### PROCEDURES

The procedure for this study has two parts. The first part focuses on obtaining the microstructure and mechanical properties of DP 600, then examining the fractured surface obtained from the tensile test. The data must be gathered in the rolling and transverse direction based on the sheet metal rolling of the sample because the physical and mechanical properties may differ in orientation. The second part of the study focuses on examining the edge topology of the mechanically sheared edge.

#### Microstructure of DP 600

To obtain a clear microstructure with the optimal microscope for the DP 500 sample, a section from the asreceived sample (the sample the way it was received) in both the rolling and transverse direction must be prepared. A small section is cut from the sample in the appropriate direction and is grinded, polished, and chemically etched with an aqueous solution of 2% nitric acid. After preparing the sectioned sample, the sample is examined under the optimal microscope using ImagePro software and the images are obtained in three layers. The samples are placed in a labeled storage bag. The layers are later compared for differences in the microstructure, such as the distribution on the ferrite and martensite phase.

#### Tensile test of DP 600 with DIC and analysis

To prepare the specimens for the tensile test, the specimens are given symmetric arched edges to allow the fracture to develop in the low width section. To aid the tracking of DIC, one side of the specimen is cleaned on the gage portion and spray-painted to have a white background with random small black spots. The prepared specimen is mounted in the 100kN Instron machine, and the digital camera is aimed at the specimen's neck region in the direction perpendicular to the specimen surface with a focus on the speckled pattern. The digital imaging is started in movie mode, and the tensile test is ran until the specimen fails. The tensile test is completed for two specimens in rolling direction and two specimens in the transverse direction. To analyze the DIC strain, the movie is converted to a sequence of images. Using the LabView software, the displacement for true strain from one frame to another is obtained over the testing time. Then, the recorded load vs. time curve provided the true stress over testing time. Then align the true stress and true strain over the same time scale by tracking back the image frame times, and finally plot a true stress vs. true strain curve for each tensile test.

#### Examining fractured surfaces with SEM

After cleaning the sample with the fractured surface using acetone in the ultrasonic cleaner and a dryer, the sample is mounted onto the SEM stage and into the SEM chamber to start the two-stage vacuum pump. The SEM is started. Then, the fractured surfaces are observed and the micrographs are recorded.

#### 3D laser scanning microscopy

The fractured region of the tested tensile specimen is cut from the specimen and placed under the 3D laser microscope to measure the surface topology. The results of the surface scanning provided the z-coordinates or height of the surface. The generated data provides the surface plot that can reproduce the image in Matlab and other advanced analysis.

#### Effect of edge topology

To study the effect of the edge topology of the mechanically sheared black on edge cracking in edge stretch forming, a 3-arc sided tensile specimen is prepared by shearing for analysis with the 3D scanning microscopy. The specimen is first analyzed as sheared, then analyzed as roughly filed with a better edge surface finish, and finally analyzed as a smoothly polished edge. Then edge roughness provided by the 3D laser microscope is correlated to the materials formability given by the total strain to fracture.

#### RESULTS

To characterize the micro-cracks and correlate micro-cracking to formability, the microstructure with emphasis on the martensite distribution, true stress vs. true strain curve from tensile testing, and the morphology and topology of the fractured and sheared surfaces must be correlated. Each step of the procedure takes time to master and complete, so the entire project will be completed by next year. Time was a significant limitation in this study. The following results, discussion, and conclusion will focus on the microstructure obtained and the expected results for the edge scanning and tensile test.

The obtained microstructure images of the DP 600 sample in the rolling direction from the optimal microscope do not show any significant difference among the martensite distribution of the different layers. The observation did reveal slight imperfections that were not removed from polishing, but those sections were not pictured. In a clear microstructure, most grain boundaries are visible. The expected results of the edge scanning are images and heights of peaks at the microstructure level of the 3-sided-arc edge of a DP 600 sample.

The tensile test will provide elongation and load data that is converted into the stress and strain curve. The name DP 600 implies that the ultimate tensile strength (UTS) should be about 600 MPa. UTS is the maximum engineering stress level the material can handle without reaching fracture. Previous studies have obtained an ultimate tensile stress of 611 MPa and a yield stress with a 0.2% offset of 367 MPa (Wu et al., 2012). Yield stress is obtained at an offset to measure the elastic limit, which is the greatest stress a material can withstand without reaching plastic deformation (NDTResourceCenter, 2014). After the tensile test, the analysis of the fractured edge with SEM and edge scanning will reveal the micro-cracks.

#### DISCUSSION

The expected results of the study will answer the central question of this project by providing images and information on the cracked edges of dual phase steels. Although the procedures for this project will not characterize micro-cracks, the relationship between the micro-cracks and formability will be analyzed. Despite difficulties with obtaining a clear microstructure, the microstructure images obtained for DP 600 resembled the microstructure images provided by Wu et al. (2012). The new cost-effective imaging technique for DIC that Dr. Wu introduced works well. McCormick and Lord (2010) support the DIC findings by explaining how new software techniques can allow conventional consumer digital cameras to capture surface deformation to one part per million of the field of view. This imaging technique will work with other types of material, however the results from the tensile test analysis is applicable to only DP 600. Kadkhodapour et al. (2011) has examined how fractures in dual phase steel affect the ferrite and martensite phases in the microstructure differently. However,

the correlation between micro-cracking and formability in DP 600 from the expected results will create precedence for the correlation between micro-cracking and AHSS. The edge topology obtained with the 3D laser-scanning microscope is a new testing measure to link edge fracture to topological features.

#### CONCLUSION

The goal of this study is to gain more insight into micro-cracking of DP steels and formability. Dual phase steels are a common type of AHSS used in the auto industry. The steel and auto industry requires more research in micro-cracking. Engineering designs for processing tools need to consider how to reduce edge-cracking. The results of this completed study will identify the correlation between micro-cracking and formability, but will not include the characterization of the observed micro-cracks. The continuation of this project will complete the tensile test with DIC, image analysis of the fractured edges, and edge topology of a 3-sided arc edge at different roughness. Most of these procedures have been studied and practiced up to this point of the study, but not with the actual DP 600 samples to yield results. Additional procedures, could aid in seeing the effects of the fracture at the microstructure level and further lengthen the study. Future studies could test other types of AHSS, such as TRIP, and higher strengths of DP for comparison with the results of DP 600.

#### REFERENCES

Avramovic-Cingara, G., Ososkov, Y., Jain, M. K., & Wilkinson, D. S. (2009). Effect of martensite distribution on damage behaviour in DP600 dual phase steels. *Materials Science and Engineering: A*, *516*(1–2), 7-16. doi: <u>http://dx.doi.org/10.1016/j.msea.2009.03.055</u>

Demeri, M. Y. (2013). *Advanced high-strength steels: Science, technology, and applications*. Materials Park, OH: ASM International.

Evin, E., Tomas, M., Katalinic, B., Wessely, E., & Kmec, J. (2013). Design of dual phase high strength steel sheets for autobody. *DAAAM International Scientific Book*, 767+.

Ghadbeigi, H., Pinna, C., Celotto, S., & Yates, J. R. (2010). Local plastic strain evolution in a high strength dual-phase steel. *Materials Science and Engineering: A*, *527*(18–19), 5026-5032. doi: <u>http://dx.doi.org/10.1016/j.msea.2010.04.052</u>

Kadkhodapour, J., Butz, A., Ziaei-Rad, S., & Schmauder, S. (2011). A micro mechanical study on failure initiation of dual phase steels under tension using single crystal plasticity model. *International Journal of Plasticity*, 27(7), 1103-1125. doi: <u>http://dx.doi.org/10.1016/j.ijplas.2010.12.001</u>

Kolbasnikov, N. G., Bezobrazov, Y. A., & Naumov, A. A. (2013). Structural evolution of high-strength dualphase steel in hot rolling. *Steel in Translation*, *43*(7), 455-459. doi: 10.3103/S0967091213070085

Kuykendall, W. (2013). Proposal for DIC module for instron 5585H. from techfee.washington.edu/proposals/2014-012/

Kuziak, R., Kawalla, R., & Waengler, S. (2008). Advanced high strength steels for automotive industry. *Archives of civil and mechanical engineering*, 8(2), 103-117.

Liewald, M., & Radonjic, R. (2014). Behavior of advanced high strength steels in deep drawing processes. *Annals of the Faculty of Engineering Hunedoara*, *12*(1), 141-146. McCormick, N., & Lord, J. (2010). Digital image correlation. *Materials Today*, *13*(12), 52-54. doi: <u>http://dx.doi.org/10.1016/S1369-7021(10)70235-2</u>

NDTResourceCenter. (2014). Tensile Properties. from https://www.ndeed.org/EducationResources/CommunityCollege/Materials/Mechanical/Tensile.htm

Wu, X., Bahmanpour, H., & Schmid, K. (2012). Characterization of mechanically sheared edges of dual phase steels. *Journal of Materials Processing Technology*, *212*(6), 1209-1224. doi: <u>http://dx.doi.org/10.1016/j.jmatprotec.2012.01.006</u>

Xiaodong, Z., Zhaohui, M., & Li, W. (2005). Current status of advanced high strength steel for auto-making and its development in Baosteel: Baosteel.

# LANTHANIDE BASED WATER-TOLERANT ASYMMETRIC CATALYSIS OF THE MICHAEL REACTION

By Joshua L. Fischer Major: Chemistry Mentor: Dr. Matthew Allen, Department of Chemistry

#### ABSTRACT

The development of water-tolerant methods to perform carbon-carbon bond forming reactions is a desired research area because such reactions can synthesize many bioactive molecules, such as pharmaceuticals. Performing these reactions in aqueous conditions generates an economic advantage by eliminating the need for costly, rigorously dried solvents. The asymmetric Mukaiyama aldol reaction has been carried out in aqueous environments using a variety rare-earth based precatalyst previously synthesized in our lab. In this work the catalyst's efficacy was tested in the Michael reaction using a scope of different Michael donors in conjunction with a variety of different lanthanide bases for the catalyst.

#### LIST OF TERMS

**Aldehyde**: An organic molecule containing a terminal acyl (C=O) group.

**Alkyl**: A functionality of an organic molecule that has been added by removing a hydrogen from the terminal carbon.

**Amine**: An organic molecule containing single bonded nitrogen (nitrogens are commonly represented with the term aza).

**Aromatic**: When a conjugation of unsaturated bonds, lone pair, or empty orbitals interact to form a compound stronger than expected.

Aryl: A functionality of an organic molecule that is aromatic.

Aqueous: A solvent that is or contains water.

Chiral: A molecule is not superimposable with its own mirror image.

**Crown ether**: A cyclic organic molecule containing Lewis bases such as O or N typically used to chelate metals.

**Cyclen**: An 12 membered cyclic organic molecule containing amine groups at the 1,4,7, and 10 positions.

**Diastereomer**: A molecule with the same composition but different spatial configuration that is not an enantiomer.

Enantiomer: The mirror image of a molecule with chiral centers.

**Enolate**: An organic molecule containing an alkene with a oxygen anion attached to one of the unsaturated carbons.

**Ester**: An organic molecule that contains an acyl group bonded to an ether group ( $R_1COOR_2$ ).

**Ketone**: An organic molecule containing a non-terminal acyl group. **Lanthanoid**: Group 3 elements that behave similarly to, but are not, lanthanides.

Lewis acidity: A species capable of receiving a pair of electrons from an electron donor.

Ligand: A molecule that binds or coordinates to a metal center by donating electrons.

**Thin layer chromatography**: A characterization technique in which a glass plate coated with silica gel and is used to separate compounds by affinity. This is done by allowing a solvent to diffuse along the plate. Compounds with a lower affinity for the silica travel farther along the plate, carried by the solvent. **Transition metals**: The group of elements in the periodic table ranging from group 3 to group 13. **Silyl enol ether**: An organic molecule containing an enolate bonded through its terminal oxygen to an organic silyl group.

**Stereoselective**: Choosing a particular spatial configuration (chirality).

Steric: The volume of space an atom occupies.

Recently lanthanides have attracted attention due to their strong Lewis acidity, which affords them the ability to catalyze a variety of reactions such as the Mukaiyama aldol and Michael reactions (Jenner, 1999). The products of these carbon–carbon bond forming reactions can be used in the synthesis of bioactive molecules and often contain chiral centers. Because biological processes are sensitive to the chirality of a molecule (such that compounds of the wrong chirality may not perform as well if at all), control of the chirality of the products of these reactions is desired. This control can be achieved through the use of a catalyst. Traditional catalysts (such as TiCl<sub>4</sub>) are very reactive with water and require the use of costly dried organic solvents, generating a demand for water–tolerant catalysts capable of controlling stereochemistry in these powerful carbon–carbon bond forming reaction, but many tend to require costly rigorously dried solvents (Mei, Dissanayake, & Allen, 2010; Lindström, 2002). Surprisingly little effort has been put forth into developing such stereospecific Lewis acid based precatalysts for the Michael reaction, increasing the demand for such a compound (Lindström, 2002).

To that end Allen *et. al.* have developed a class of lanthanide based water-tolerant asymmetric precatalysts for use in the Mukaiyama aldol reaction (Mei, Averill, & Allen, 2012; Mei, Dissanayake, & Allen, 2010). They hypothesized that the precatalyst employs such good stereoselectivity through coordination of the substrate (a molecule coordinating through an acyl group) to a lanthanide chelated by a chiral ligand. The chiral environment imparted onto the lanthanide by the ligand sterically hinders the formation of undesired enantiomers, resulting in excellent stereoselectivity. The Michael reaction follows a similar mechanism. The Michael acceptor contains an acyl group which must be activated (which can be achieved through coordination to a Lewis acid, such as a lanthanide) before the reaction can occur (Ding, Katebzadeh, Roman, Bergquist, & Lindström, 2005; Denmark, Wong, & Stavenger, 1997; Denmark & Heemstra, 2003; Desimoni, Faita, Piccinini, & Toscanini, 2006). Because the mechanism of the Lewis acid catalyzed Michael reaction is remarkably similar to the Mukaiyama aldol reaction I have hypothesized the family of Allen's precatalysts may be adapted for use in the Michael reaction. By the addition of a chiral environment to a lanthanide, stereoselectivity of the products can be achieved.

#### LITERATURE REVIEW

Keller and Feringa reported the use of a lanthanide salt (ytterbium) as a precatalyst in an aqueous Michael reaction (1996). Interestingly, the reaction was carried out in pure water, which would not dissolve all of the organic reagents, forming suspensions. They note that the suspension reactions were tested with a variety of reagents showing impressive results compared to other literature published at the time. It should be noted that Keller and Feringa also performed a negative test, adding the Michael reagents to a solution of water without the presence of the ytterbium metal. After fourteen days the reaction without ytterbium had only progressed half as much as a three day reaction with ytterbium present, implying that the lanthanide was catalyzing the reaction.

Keller and Feringa's work with Lewis acid catalyzed water syntheses provide a solid support for aqueous Michael reactions. However it should be noted that all of the products produced contained chiral centers, but the actual chirality of the products were not determined. This formation of chiral centers with a new carbon–carbon bond attracts the idea of an asymmetric precatalyst for the reaction. It should also be noted that in preliminary work with the Michael reaction in our lab included organic solvent into a similar reaction which lowered the

reaction time from days (reported in Keller and Feringa's work) to hours while maintaining quantitative yields. This is most likely due to the suspensions isolating reactants within the imulsion and limiting their access to the lanthanide precatalyst.

In a later work by Kobayashi and Manabe, a variety of metal salts were used to catalyze the Mukaiyama aldol, Diels–Alder, and the Michael reactions in aqueous conditions (2001). The reactions were carried out using transition metal and lanthanoid salts as precatalysts (some with chiral ligands) to afford stereoselective products. They found that the addition of water to the reaction improved the yield of some reactions from as low as 10% to as high as 91%. The addition of water also improved the enantioselectivity of the products by a factor of about two, implying the addition of water not only activates the catalyst but improves the stereoselectivity.

Kobayashi, Manabe, Keller, and Feringa have demonstrated that water is an overlooked medium for organic synthesis; water is not normally considered due to insolubility of the reagents. The work performed by Kobayashi and Manabe was extensively interested in the Mukaiyama aldol reaction, which is a famous (and powerful) method for constructing complex organic molecules, but also other reactions including the Michael reaction. Kobayashi and Manabe catalyzed the reaction with scandium, a lanthanoid, with great success. The aqueous Michael reaction resulted in a 96% yield and was carried out at room temperature in pure water. The product did contain a chiral center, but the enantiomeric ratio was not determined.

An interesting statement in their report is the suggestion to include crown ethers with chiral pendant arms to induce stereoselectivity. Crown ethers can be functionalized by substituting amines in place of ethers, allowing the addition of chiral pendant arms. The use of crown ethers to chelate Lewis acidic metals lends itself to using chiral crown ethers to catalyze the aforementioned reactions, including the Michael reaction.

In addition to Kobyashi's work, Mei, Dissanyake, and Allen have focused on the use of chiral ligands to create lanthanide-based metal complexes for use in the water-tolerant Mukaiyama aldol reaction (2010). Mei *et. al.* generated a new class of ligands based upon a 1,7-dioxa-4,10-diazacyclododecane base with ester arms added at the amines. The arms contain chiral centers providing a chiral environment for the substrate upon coordination to a metal, limiting accessibility to the reactive site of the aldehyde or ketone through steric hindrance. The chiral ester of the ligand was functionalized with a variety of alkyl and aryl groups, with most functionalities yielding good to excellent results.

In the synthesis of the chiral ligands, it was found the selectiveness of the products were dependent on the diastereomeric and enantiomeric ratios of the ligand. By enhancing the diastereomeric ratio of the ligand from 5:1 to >99:1, the enantiomeric ratio of the product increased from 89:1 to 93:1. The study only enriched the diastereomeric ratio of one ligand, a bis-2-methylpropanoate (most likely due to the arduous purification time and inherent success of the ligand before enrichment). Their decision to enrich this ligand has led me to examine it for its effectiveness in the Michael reaction due to the incredible similarity of the mechanism of the Michael reaction to the Mukaiyama aldol reaction.

In a more recent study Mei, Averill, and Allen use different synthetic routes to synthesize the ligand in an attempt to enhance the diastereomeric ratio (2012). This was done by altering the solvents used and resulted in increasing the diastereomeric ratio from 5:1 to 16:1. Also, because the Lewis acidity of lanthanides is partially dependent on the size of the metal, they screened a variety of different lanthanides (which have varying ionic radii) in order to determine the effect of charge density on the Mukaiyama aldol reaction. They found neodymium to be the best choice.

Again, because of the similarity of the mechanism between the two reactions, neodymium has potential to be one of the best candidates for my own research. However, due to electronic differences in substrates and a different point of carbon–carbon bond formation it is possible that neodymium will not be as effective as other lanthanides, so Mei's best three metals will screened (neodymium, gadolinium and europium). This allows a "tuning" of the precatalyst to the Michael reaction by altering the ionic radius of the metal contained within the precatalyst. In the most recent work by Averill and Allen, the possible coordination of more than one ligand to the lanthanide metal center was investigated. By using NMR and luminescence spectroscopy they determined that in specific conditions more than one ligand does coordinate to the lanthanide altering the accessibility–and therefore reaction time–of substrates to the lanthanide. In a ligand to metal ratio of 2.4:1 there are two ligands bound to the metal (Eu), saturating the environment, forcing a substrate to partially displace the ligand to become activated. This effect causes the reaction times to take much longer than a ratio of 1.2:1, where only one ligand is bound to the metal.

The results of this article illustrate the need to consider the ligand to metal ratio used in my own work. The stereoselectivity of the products was maintained when a 2:1 ligand, but access to the activation site was hindered by extra bulk from the ligand, slowing the reaction. This additional crowding has the potential to offer extra selectivity in the Michael reaction by expanding the chiral environment. Because the reaction site is located three atoms away from where the substrate will bind to the lanthanide the reaction environment is different. The additional space occupied by the ligand may induce selectivity that might not be possible in the 1.2:1 ligand to metal ratio.

In a very recent work by Robinson, Yadav, Fan, Stanton, Schelter, Pericás, and Walsh the Michael reaction was catalyzed using a combination of Shibasaki's ligand (perhaps one of the most effective and versatile asymmetric catalysts produced) and a variety of amine containing molecules including cyclen (2014). This work is of particular interest because of the similarity of cyclen to the 1,7-dioxa-4,10-diazacyclododecane base used in my own work. While a variety of different precatalysts were screened in the work, the cyclen based precatalyst showed promising results. Walsh *et. al.* reported a 96% yield with a 53:1 enantiomeric ratio at room temperature.

The enantiomeric ratio is not ideal. it should be noted the reaction was carried out at room temperature. However, there was one reaction reported at -35 °C which produced an 80:1 enantiomeric ratio. While the lanthide is bound within Shibasaki's ligand (which contains much more bulk than the ligand I have proposed) the inclusion of cyclen to effect the stereoselectivity of the product implies there is potential for the precatalyst I have proposed to use.

#### METHODS

#### Synthesis of (S)-methyl 2-bromopropanoate

A 10-mL round bottom was filled with SOCl<sub>2</sub> (1.2 eq., 0.69 mmol, 0.31 mL) and then charged with Ar using by sealing the vessel from the atmosphere with a septa and a inserting positive flow of Ar gas. The vessel was then placed under vacuum and refilled with Ar. This was repeated three times to assure the removal of any water. (*S*)-2-bromopropanoic acid (1.0 eq, 0.58 mmol, 0.29 mL) was then added to the vessel with a syringe and needle. The mixture was shaken gently and heated to 60 °C and left to react for 12 h. The vessel was removed from heat and allowed to cool to ambient temperature then cooled to 0 °C. The resulting clear yellow mixture was added dropwise over 1 min to an open vial of dry CHCl<sub>3</sub> (5.0 mL), MeOH (3 eq, 1.725 mmol, 0.29 mL), and pyridine (1.5 eq, 0.86 mmol, 0.29 mL) at 0 °C which was immediately sealed and placed in an ice bath. The mixture was left to react in the ice bath for 2 h, removed from the ice bath and left at ambient temperature for 1 h. The resulting clear yellow solution was then rinsed with water (15 mL), 10 % H<sub>2</sub>SO<sub>4</sub> (20 mL), and saturated Na<sub>2</sub>CO<sub>3</sub> (20 mL). The reaction mixture was concentrated under reduced pressure at 0 °C resulting in a thin clear oil. The identity of compound was verified by NMR spectroscopy against previously reported spectra. 92 %, 0.53 mmol, 88 mg.

#### Synthesis of (2S,2'S)-dimethyl 2,2'-(1,7-dioxa-4,10-diazacyclododecane-4,10-diyl)dipropan- oate

CHCl<sub>3</sub> (5.0 mL) was added to a round bottom flask equipped with a stir bar. 1,7-dioxa-4,10-diazacyclododecane (1 eq, 0.14 mmol, 25 mg) and (S)-methyl 2-bromopropanoate (6 eq, 0.84 mmol, .082 mL) were added to the vessel. The mixture was left for 72 h with stirring then the mixture was concentrated under reduced pressure. The resulting yellow oil was dissolved in Et<sub>2</sub>O (7.0 mL) and extracted with water (3x7.0 mL). The organic layer

was concentrated under reduced pressure resulting in a clear yellow oil. The identity of the compound was verified by NMR spectroscopy against previously reported results. The enantiomeric ratio (10:1) was determined using HPLC (Chirapak OJ-H column, 95:5:0.01 hexanes/isopropyl alcohol/ diethyl amine, 0.3 mL/s flowrate). 92 %, 0.13 mmol, 46 mg.

#### MICHAEL REACTION

In a 4-mL vial ethyl 2-oxocyclohexanecarboxylate (3.7 eq, 60  $\mu$ L, 0.69 mmol) and but-3-en-2-one (1.0 eq, 31.6 mg, 0.19 mmol), and Eu(OTf)<sub>3</sub> (0.2 eq, 22.7 mg, 0.038 mmol) were added to 10:1 EtOH/H<sub>2</sub>O equipped with stirring. The reaction was left for 6 h (until starting materials were no longer distinguishable by TLC). Volatiles were removed under reduced pressure and the remaining residue was redissolved in Et<sub>2</sub>O (1.5 mL) and extracted with H<sub>2</sub>O (3x1.5 mL). The organic layer was collected under reduced pressure and triturated with toluene (3x3.0 mL) to remove any water. The resulting clear yellow oil was characterized by NMR spectroscopy. 77%, 0.15 mmol, 33 mg.

#### RESULTS

Chiral ester **B** was synthesize successfully in high yield following Scheme 1. This efficient synthesis was performed by carefully considering the properties of the reactants, products, and intermediates. Initially full three step extractions of water,  $H_2SO_4$ , and saturated  $Na_2CO_3$  instead of a rinse were used to purify **B**. This resulted in a residual opaque, white crystal suspended in the product. It was initially hypothesized that this crystal was a pyridinium salt and multiple attempts to remove the salt were attempted. Each subsequent attempted lead to a loss of product, but the crystal remained. It was determined that the crystal forming was a reversion of **B** to its carboxylic acid form **A**. Adapting the extractions to a rinse afforded a clear oil with no solids, effectively removing the crystals.

Scheme 1: Synthetic route used to synthesize the bromomethyl ester necessary for synthesis of the chiral ligand.



Other considerations were taken regarding the initial and intermediate states of the reaction. Both are sensitive to water, requiring an atmosphere completely void of water. This accommodation allows high yield of the products. Also, the intermediate state is volatile (boiling at above room temperature when under reduced pressure). By adjusting the temperature to 0 °C when removing volatiles fears of losing product during the process were abated. Chiral ligand **E** was then easily synthesized using bromoester **C** (Scheme 2).

Scheme 2: Synthetic route used to synthesize the chiral ligand



The Michael reaction was tested using a  $Eu(OTf)_3$  precatalyst and found to proceed under the conditions indicated. The reaction produced a yield of 77%. This preliminary study proves that  $Eu^{3+}$  is capable of catalyzing the reaction, though it is not certain if the addition of a chiral ligand will perform well or provide stereoselectivity.

Scheme 3: The Michael reaction under investigation



#### DISCUSSION

Research is still in preliminary phases and further testing will need to be conducted before any conclusions can be drawn regarding the use of the chiral ligand **E** with different lanthanides. I have hypothesized that due to the different spatial location of the reactive site of the Michael acceptor and the aldehyde in the Mukaiyama aldol reaction the precatalyst may need to be "tuned." This can be achieved through several methods, but I have chosen to examine both using different lanthanides and modifying chiral ligand **E**. Because of the lanthanide contraction as lanthanides increase in atomic weight the radius of the lanthanide decreases from lanthanum (1.17 Å) to lutetium (1.00 Å) (Wooten, Carroll, Walsh, 2008). By varying the ionic radii the lanthanide will bind the Michael acceptor more tightly because of the higher charge density, drawing the reactive site deeper within the chiral environment. Another method is to enlarge the environment of the ligand by altering the ester arms. The direction the esters face is determined by the chiral center located on the arm. By increasing the size of the ester arms the chiral environment is essentially increased as well.



*Figure 1:* Proposed transition state of the Michael reaction (left) and the Mukaiyama aldol reaction (right), demonstrating the different location of the reactive site, shown with the red circle.

#### RECOMMENDATIONS

The research outlined will be concluded by testing the Michael acceptors and donors outlined in Table 1. Each Michael donor with be tested against each Michael acceptor, yielding a total of nine different products. The substrates were chosen to test the versatility of the precatalyst; each acceptor increases in size to determine the steric limits of the precatalyst. From the data collected from these experiments the effectiveness of the asymmetric precatalyst will be determined.

Synthesis of the precatalyst is both expensive and time intensive. These factors make recovery of the precatalyst an attractive option. In order to aid in the recovery, attempts will be made to bind the precatalyst to a solid resin bead. This would allow the precatalyst to be recovered by simply filtering off and rinsing the resin, after which the resin could be recycled for other reactions. This increased turnover would result in an economical precatalyst which (if the Michael reaction is successful) which is also versatile.

Table 1: Substrate scope for future Michael reactions

#### **Michael acceptors**



#### **Michael donors**



Lanthanides have also been used to catalyze a variety of other chiral organic reactions such as the Henry, Diels-Alder, and aza-Diels-Alder reactions, to name a few. Substituting aqueous conditions for expensive dry organic solvents provides a financial appeal, meriting further studies into the versatility of the precatalyst. However, which reactions to study have not been determined.

#### REFERENCES

Averill, D. J., & Allen, M. J. (2014). Synthesis, Spectroscopic Characterization, and Reactivity of Water-Tolerant Eu3+-Based Precatalysts. *Inorganic Chemistry*. doi: 10.1021/ic500790q

Denmark, S. E., & Heemstra, J. R. (2003). Lewis Base Activation of Lewis Acids. Catalytic Enantioselective Addition of Silyl Enol Ethers of Achiral Methyl Ketones to Aldehydes. *Organic Letters*, *5*(13), 2303-2306. doi: 10.1021/ol0346411

Denmark, S. E., Wong, K.-T., & Stavenger, R. A. (1997). The Chemistry of Trichlorosilyl Enolates. 2. Highly-Selective Asymmetric Aldol Additions of Ketone Enolates. *Journal of the American Chemical Society*, *119*(9), 2333-2334. doi: 10.1021/ja9636698

Desimoni, G., Faita, G., Piccinini, F., & Toscanini, M. (2006). Enantioselective Mukaiyama-Aldol Reaction of Pyruvates and 1-Phenyl- 1-trimethylsilyloxyethene Catalyzed by Lanthanide/Pybox Complexes. *European Journal of Organic Chemistry*, 2006(23), 5228-5230. doi: 10.1002/ejoc.200600716

Ding, R., Katebzadeh, K., Roman, L., Bergquist, K.-E., & Lindström, U. M. (2005). Expanding the Scope of Lewis Acid Catalysis in Water: Remarkable Ligand Acceleration of Aqueous Ytterbium Triflate Catalyzed Michael Addition Reactions. *The Journal of Organic Chemistry*, 71(1), 352-355. doi: 10.1021/j0051540n

Jenner, G. (1999). Effect of high pressure on Michael and Henry reactions between ketones and nitroalkanes. *New Journal of Chemistry*, 23(5), 525-529. doi: 10.1039/A900899C

Keller, E., & Feringa, B. L. (1996). Ytterbium triflate catalyzed Michael additions of  $\beta$ -ketoesters in water. *Tetrahedron Letters*, *37*(11), 1879-1882. doi: <u>http://dx.doi.org/10.1016/0040-4039(96)00141-4</u>

Kobayashi, S., & Manabe, K. (2002). Development of Novel Lewis Acid Catalysts for Selective Organic Reactions in Aqueous Media. *Accounts of Chemical Research*, *35*(4), 209-217. doi: 10.1021/ar000145a Lindström, U. M. (2002). Stereoselective Organic Reactions in Water. *Chemical Reviews*, *102*(8), 2751-2772. doi: 10.1021/cr010122p

Mei, Y., Averill, D. J., & Allen, M. J. (2012). Study of the Lanthanide-Catalyzed, Aqueous, Asymmetric Mukaiyama Aldol Reaction. *The Journal of Organic Chemistry*, 77(13), 5624-5632. doi: 10.1021/jo300800b

Mei, Y., Dissanayake, P., & Allen, M. J. (2010). A New Class of Ligands for Aqueous, Lanthanide-Catalyzed, Enantioselective Mukaiyama Aldol Reactions. *Journal of the American Chemical Society*, *132*(37), 12871-12873. doi: 10.1021/ja107197p

Mori, Y., Kakumoto, K., Manabe, K., & Kobayashi, S. (2000). Michael reactions in water using Lewis acid–surfactant-combined catalysts. *Tetrahedron Letters*, *41*(17), 3107-3111. doi: <u>http://dx.doi.org/10.1016/S0040-4039(00)00319-1</u>

Robinson, J. R., Yadav, J., Fan, X., Stanton, G. R., Schelter, E. J., Pericàs, M. A., & Walsh, P. J. (2014). Non-Covalent Immobilization of Rare Earth Heterobimetallic Frameworks and their Reactivity in an Asymmetric Michael Addition. *Advanced Synthesis & Catalysis*, *356*(6), 1243-1254. doi: 10.1002/adsc.201400087

Wooten, A. J., Carroll, P. J., & Walsh, P. J. (2008). Insight into Substrate Binding in Shibasaki's Li3(THF)n(BINOLate)3Ln Complexes and Implications in Catalysis. *Journal of the American Chemical Society*, 130(23), 7407-7419. doi: 10.1021/ja7107933

#### APPENDIX



Mass spectrum of (2S,2'S)-dimethyl 2,2'-(1,7-dioxa-4,10-diazacyclododecane-4,10-diyl)dipropan- oate

 $NMR\ spectrum\ of\ (2S,2'S)-dimethyl\ 2,2'-(1,7-dioxa-4,10-diazacyclododecane-4,10-diyl) dipropan-\ oate$ 





# MODELING POSTTRAUMATIC STRESS DISORDER AND ITS TREATMENTS

By Donovan Garmo Major: Psychology Mentor: Dr. Shane Perrine, Department of Psychiatry & Behavioral Neurosciences

#### ABSTRACT

Post-traumatic stress disorder (PTSD) is a psychiatric disorder that develops in the aftermath of exposure to a traumatic event and is characterized by the reoccurring memories of the traumatic event, hyperactivity, avoidance and disrupted emotion and cognition. Paroxetine (PRX), which is a selective serotonin reuptake inhibitor (SSRI), is one of only two FDA-approved medications for treatment of PTSD, yet the mechanism of action for PRX's therapeutic effects in PTSD is not completely understood. This prompted Dr. Perrine's lab to conduct a set of experiments in mice to study the disruptive effects of trauma on recognition memory and to determine how PRX reduces the effects of traumatic stress exposure on cognition. My role was to learn and use two programs (Ethovision and J-Watcher) to manually score pre-recorded videos of the mouse behaviors. We expected that mice who received single prolonged stress would show a decrease in novel object recognition behavior, a reflection of PTSD-like behavior. Furthermore, we expected PRX to reverse the effects of traumatic stress exposure. Dr. Perrine's lab also isolated the brains of the mice following the behavioral testing. My second role was to learn the operation of high pressure liquid chromatography (HPLC) equipment to measure serotonin levels in brain tissue. Furthermore, I used HPLC to measure levels of serotonin and other monoamines to determine if traumatic stress exposure changes these neurochemical levels and if PRX reverses this effect. In both parts of the project, I was responsible for measuring and analyzing data under the direction of Dr. Perrine and members of his lab group. I assisted in the interpretation of results. Finally, I aim to present my findings at an upcoming McNair program meeting and at WSU Undergraduate Research Day.

#### MODELING POSTTRAUMATIC STRESS DISORDER OF TREATMENT

Post-traumatic stress disorder (PTSD) is diagnosed in approximately eight percent of humans in America every year (National Center of PTSD) and this number is increasing with all the added wars and stress in the world today (National Center of PTSD). PTSD has four symptoms that have been classified by the DSM5 and all individuals must meet this criterion to be diagnosed with PTSD. The symptoms include re-experiencing of traumatic event (flashbacks), avoidant behavior, hyper-arousal and negative cognition/mood percent (National Center of PTSD). We will model PTSD with the paradigm of single prolonged stress (SPS) (Khan and Liberzon 2004; Kohda et al. 2007) which uses the method of a series of acute stressors on the mice. The SPS paradigm is a valid model because it mimics many of the effects seen in PTSD, including changes in the hypothalamic-pituitary-adrenal axis (HPA axis) function. This research on PTSD is beneficial to society because if successful it can eventually aid and positively impact families, veterans, and humans around the world.

#### LITERATURE REVIEW

Yamamoto and Morinobu (2009) suggested that single prolonged stress (SPS) (Khan and Liberzon 2004; Kohda et al. 2007) is the best model and phenotype for posttraumatic stress disorder (PTSD) in rodents that has been developed to date but still shows some limitations that includes the inability to use of transgenic mouse models. SPS mimics similar characteristics that a patient with PTSD would exhibit. Yamamoto and Morinobu (2009) use selective serotonin reuptake inhibitors (SSRI) such as paroxetine (PRX) to help alleviate the characteristics of PTSD. The rats were administrated through SPS which consists of a series of stressors which begins with a 2

hour restraint followed by a 20 minute forced swim, then a 15 minute recuperation period, then the mice were exposed to ether for 5 minutes followed by a 7 day undisturbed period. The test conducted was to examine behavioral activity in response to the forced swim test (FST) which helped asses the fear in SPS rats. The rats in the SPS group when through SPS and then had an FST session and then had an undisturbed rest period for 7 days and then had the second FST for 5 minute. In the control group the rats went through a forced swim for 20 minutes but did not receive SPS, followed by a 7 day rest period and then had another FST for 5 minutes. Both groups were measured for immobility in comparison with the first FST session which was the first 5 minutes of the 20 minute period. The rats were then suspended from their tails for 6 minutes and were measured for immobility.

The authors found that immobility enhanced fear response in PTSD-like symptoms, but there was not any significant differences between the control and SPS group which proposes that the SPS rats did not exhibit despair responses. This data in relation to patients with PTSD when interpreted represents that when a patient has PTSD and is in a stressful situation they feel helpless in response to the event.

The author's main viewpoints are to focus on memory abnormalities and evaluation of the validity of SPS for an animal model of PTSD. They have found that the rodents show some symptoms that are similar to PTSD and also show that PRX does aid with some symptoms of PTSD, but still feel that SPS can be improved as a model of PTSD to study the pathways and brain regions that are involved with this disorder. The author's main message is to fully understand what effects SPS has on rats and what it does to them; which they explore specific types of the brain to help reinforce that SPS is a good model to go by for a generic form of PTSD.

Hetrick and Purcell (2010) studied pharmacotherapy and psychological therapies for posttraumatic stress disorder (PTSD). PTSD is the re-experiences or flashback of a traumatic event that could cause avoidant behavior. The authors work suggests that the combination of both types of therapy would give the best results for patients with PTSD. The main goal of the study was to assess if the combination of psychological therapy and pharmacotherapy would provide a more effective treatment rather than either one of the treatments administered independently.

This study took patients of any age or gender who were diagnosed with PTSD. The clinicians took the patients and made comparisons the first comparison was the combination psychological and pharmacological intervention versus waitlist control. The second was combination psychological and pharmacological intervention versus pharmacotherapy placebo, followed by the third which was combination psychological and pharmacological and pharmacological intervention versus standard treatment; then the fourth which was combination psychological and pharmacological intervention versus pharmacotherapy alone; and lastly was the comparison of combination psychological and pharmacological intervention versus psychological therapy alone.

The primary outcomes of this research suggested that the evidence between the group receiving combined interventions to the group receiving psychological therapy or pharmacotherapy did not have any significant results. The authors found that similar results or alleviating symptoms were obtained when either of these interventions were used alone. There was little data on the other outcomes and in no case were not significant enough to report.

The authors had a good conceptual idea by assuming pharmacotherapy and psychological therapies worked separately then they should also work when combined and decrease PTSD symptoms. The data was not enough to support the study and will need to further randomize controlled trials which is required to strengthen the results. The researchers also stated that a bigger study group and sample size is needed to compare the different aspects of pharmacotherapy and behavioral treatments. This study relates to Sonne and Carlsson (2013) experiment because they similarly tried to administer Venlafaxine with psychotherapy, which is a dual-action antidepressant that works on several pathways in the brain such as a selective serotonin reuptake inhibitor and an antidepressant. They studied refugees with PTSD and in combination administered Venlafaxine with psychotherapy to see if there was a positive effect on the symptoms of PTSD. Sonne and Carlsson found that venlafaxine did show some positive effects with some of the refugees but did not help in the more complex

cases. Venlafaxine has also shown that using the drug short or long term do play a role in alleviating symptoms in both time periods.

Takahashi and Morinobu (2006) studied rats that were given single prolonged stress (SPS) which is a rodent model of post-traumatic stress disorder (PTSD). The aim for the study was to examine whether SPS can produce an enhanced psychophysiological reactivity in response to the stressors which are not related to trauma. Furthermore, to examine whether paroxetine (PRX) can alleviate anxiety and fear response in the rats which were subjected to SPS.

Four groups were used to complete the experiment, the first was the control group with vehicle, then the SPS group with vehicle followed by the control with PRX, and lastly with SPS and PRX group. The control group with vehicle did not under go SPS and were undisturbed for 14 days but on the 14<sup>th</sup> day were given foot shocks then on the 15<sup>th</sup> day were given a 24 hour rest period and then measured for contextual freezing. The SPS vehicle group were also undisturbed for 14 days then were administered shock and then were given a 24 hour rest period and were also measured for contextual freezing. The control PRX group followed by the SPS and PRX group went through similar steps and then were measured for contextual freezing.

This studied showed that PRX did alleviate symptoms of PTSD and helped with avoidant behavior. The authors had very unique experimental design in the sense that they chose PRX doses that are clinically relevant when chronically administrated. Repeated PRX administration caused significant suppression in contextual freezing. When PRX was acutely administered at a dose that was clinically relevant, it did not affect freezing. The author suggested that a plausible mechanism was that the up regulation of the shock threshold by PRX may play a role in suppressing action because fear was induced by the foot shock (Takahashi & Morinobu (2006)).

The findings that SPS and or PRX showed no significant influence on spontaneous locomotors activity in rats without fear conditioning would suggest that the alterations of freezing would not be due to the basal locomotors activity. In a study done by Hashimoto et al. (1999) which examined the changes in freezing behavior and norepinephrine release that was induced by a conditioned fear stress using microdialysis *in vivo*. Their report suggests that the increase in norepinephrine levels in the medial prefrontal cortex induced by an SSRI reduced the freezing behavior that was shown by those rats.

George and Liberzon (2014) examined the use of Phenytoin (PHE) in the SPS model. Phenytoin is an anticonvulsant which is used on patients who have trouble with seizures which helps prevent and stop seizures. The single prolonged stress (SPS) paradigm was used as a phenotype for posttraumatic stress disorder (PTSD). SPS has shown to implicate excitatory neural transmission and glucocorticoid receptor upregulation in the medial prefrontal cortex and hippocampus in fear memory abnormalities which are linked to PTSD.

50 day old rats went through the SPS paradigm which were restrained for 2 hours than had forced swim followed by a 5 minute exposure to ether. The rats were single housed for and were undisturbed for 7 days. Once SPS was administered one day after the rats were randomly assigned to one of three groups a subcutaneous injections of PHE were either 40 mg/kg, 20 mg/kg, or vehicle. Fear conditioning, extinction, and extinction retention testing was conducted. Fear conditioning consisted of five presentations of a beep which co-terminated with the foot shock. Extinction training followed fear conditioning, 24 hours later, and consisted of 30 presentation of the beep presentations without the foot shocks. Extinction retention testing consisted of ten beeps presentations and occurred in the same context as extinction and was 24 hours after extinction training.

Fear conditioning as well as extinction were unaffected by SPS or PHE. SPS did impair extinction retention but was retrieved by both doses of PHE. In similar context SPS increased glucocorticoid in the medial prefrontal cortex and also in the dorsal hippocampus; but prevented SPS induced glucocorticoid upregulation in the medial prefrontal cortex.

The results show that PHE is a good secondary preventative drug and is good for the prevention of PTSD but is not an effective pharmacotherapy drug. The data did suggest that PHE did lead to the prevention of extinction retention deficits as well as the prevention of glucocorticoid receptor upregulation in the medial prefrontal cortex and in the hippocampus. The relevance of this paper to my own work is that the researchers are attempting to discover another protective measure before PTSD is fully developed, which illustrates that PHE could be a worthy preventative drug for PTSD. If PHE was approved as a good preventative drug this could impact many lives in help prevent this life altering disorder. Cunningham et al. (2000) suggest that glutamatergic antagonism is the main mechanism of phenytoin and that during the sensitization phase of SPS the drug could prevent the development of PTSD. Cunningham et al. (2000) have found that phenytoin does help in the preventative measure of PTSD but still doesn't show effectiveness in fully developed PTSD.

Matsumoto and Morinobu (2013) use the pharmacotherapy to help alleviate fear extinction which happens in the hippocampal NMDA-CaMKII pathway of the brain. The pharmacotherapy drug was vorinostat which is a histone deacetylase (HDAC) inhibitor and has shown to enhance fear extinction in animals. The objective of the study was to see if HDAC inhibitor vorinostat could ease fear extinction symptoms.

The single prolonged stress (SPS) paradigm was used which consists of a 2 hour restrained period than had a forced swim followed by a 5 minute exposure to ether then were individually housed for 7 days. Subsequently the SPS rats received contextual fear conditioning which was followed by 2 days of extinction training. Vorinostat was intraperitoneal injected after extinction training; then followed was a contextual assessment 2 hours after the vornistat injection. The animals were then sacrificed and were tested for protein levels via western blotting or RT- PCR.

The results show that vorinostat improves the impaired extinction in SPS rats which does so by increasing NR2B and CaMKII which are both located in the hippocampus. The results also suggest that vorinostat with extinction training showed a decrease in freezing in comparison to the SPS group without extinction training. These findings show that vornistat with the combination of exposure therapy could be a promising technique for the treatment of PTSD.

Matsumoto and Morinobu (2013) took a similar experiment that has been recently done by Bredy and Barad (2008), Lattal et al. (2007), Stafford et al. (2012). *and used the drug vorinstat which is a histone deacteylase and saw that it alleviated the impaired extinction of fear memory. The author conveys that these types of histone deacteylase help in fear extinction retention and should be used because of the increase in hippocampal levels.* Barad (2008) and Lattal et al. found that histone deacteylase had an impact in the hippocampus which led Matsumoto and Morinobu (2013) to use vorinstat which exhibited similar effects of alleviating impaired fear extinction. These findings suggest that vorinostat in arrangement with exposure therapy can be an effective pharmacological method for the treatment of patients with PTSD.

Sharpless, B. A., & Barber, J. P. (2011) have been focusing in the improvement of health with patients with the disorder PTSD. Clinicians have been mixing and matching different types of therapies such as prolonged exposure, eye movement desensitization and reprocessing, and cognitive processing therapies, in combination with pharmacotherapy to determine what has the best effect on curing patients. The combination of these therapies in this study focused on traumatized veterans who saw action and compared it to those with trauma but did not serve.

The methods for this experiment was to take individuals with PTSD and then administer them with pharmacotherapy and then in combination use prolonged exposure, eye movement desensitization reprocessing, and cognitive processing therapies to see what effects did the combination have on the patients; these clinical trials were randomized.

These results show that with the combination of the therapies shows an increase in PTSD symptoms for returning veterans. These results don't study specific trauma such as rape and doesn't suggest that one therapy is more effective between the military populations. This study also does not show that these combination of therapies are effective on all types of trauma.

Sharpless, B. A., & Barber, J. P. (2011) have beneficial methods of utilizing different methods that have both been proven to be effective. For an individual with PTSD it isn't just on one level of the brain but has multiple associated parts and the effectiveness of many different types of therapy can target all these other levels to get the best outcome for the patient. The author really touched base with the combination of therapies and believes that more than two could also be effective in the future and will be conducted in future studies by their specific lab. Other authors such as Hetrick and Purcell (2010) have also done studies using two types of therapies but showed no significant difference, than if each therapy was administered alone. The literature Sharpless, B. A., & Barber, J. P. (2011) & Hetrick and Purcell (2010) show the same results; when the different types of therapies are used together it did not achieve statistical significance.

#### HYPOTHESIS

PRX has shown to be effective for alleviating the symptoms associated with memory recognition (Takahashi & Morinobu, 2006), but not with novel objects. We expect mice who did receive PRX would show decreases in novel object recognition behavior. Furthermore, we expect PRX to reverse the effects of traumatic stress exposure which it did. Takahashi and Morinobu (2006) also conducted a similar study to ours and have also found similar results; our lab is going to take the experiment one step further by running HPLC to measure the amount of monoamine levels that are present in the mice brains.

#### SIGNIFICANCE

The significance of this research is to figure out what pathways in the brain are associated when PRX is being administrated. Our research helps contribute to our knowledge of PTSD by determining what other roles PRX plays in helping alleviating symptoms. Furthermore, we have measured proteins to help get a better understanding on which brain regions are associated with PRX and what effects it played a role with (National Center for PTSD).

#### METHODS

#### Theoretical Framework

The importance of this study is to find effective remission methods that will help contribute in curing PTSD. In knowing the associated regions of the brain we can use a combination of pharmacotherapy and other therapies in conjugation to completely cure these symptoms and or disorder. The research problem still exists because even when pharmacotherapy is being used patients can still exhibit flashbacks which could cause them to feel that traumatic feeling.

#### **Participants**

In this research we used male mice weighing 25-30 grams.

#### Materials

A Dell desktop computer with windows 7 was used. The software Ethovision and J-Watcher were used to record and score the mice when in close proximity of the novel object. Mice cages which were used to facilitate the animals, novel objects, 50mL conical tube was used for restraint, ether, water bucket for forced swim and also water.

#### Procedure

The mice were acclimated to the animal facility which was then exposed to the single prolonged stress (SPS) paradigm. The SPS paradigm is a series of stressors which consisted of a 2 hour restraint followed by a 20 minute forced swim, then a 15 minute recuperation period, then the mice were exposed to ether for 5 minutes

followed by a 7 day undisturbed period. During the 7 day period the mice were given subcutaneous injections of PRX. The mice were then split into two cohorts with two novel objects per cohort. The mice were then placed into chambers, in which they were recorded by the program Ethovision and were scored every time they came in close proximity with the novel object with the program J-Watcher.

#### CONCLUSION AND RECOMMENDATIONS

In conclusion our lab found that PRX one of the Food and Drug Administration approved drugs helped alleviate novel object recognition of the trauma and also showed that SPS is good phenotype for PTSD but still has its limitations. We have found that PRX is effective drug on mice with PTSD and has many different types of literature to help back it up. My position on the effectiveness of the drug PRX is very strong due to the evidence and significance of these results that help strengthen the argument that PRX does help alleviate PTSD like symptoms in memory recognition. The mechanism and pathways that PRX takes are still somewhat unclear but researchers are currently attempting to discover these pathways with their findings. This experiment will contribute to the veterans who are diagnosed with this disorder and will help lessen the four aspects of PTSD so they may return to a normal quality of life. Future research and or advancement will be to introduce another type of paradigm that is a better phenotype for PTSD and compare these results with past findings.

#### REFERENCES

Cunningham MO, Dhillon A, Wood SJ, Jones RS (2000) Reciprocal modulation of glutamate and GABA release may underlie the anticonvulsant effect of phenytoin. Neuroscience 95:343–351

George, S. A., Rodriguez-Santiago, M., Riley, J., Rodriguez, E., & Liberzon, I. (2014). The effect of chronic phenytoin administration on single prolonged stress induced extinction retention deficits and glucocorticoid up regulation in the rat medial prefrontal cortex. *Psychopharmacology*.

Hashimoto S, Inoue T, Koyama T (1999) Effects of conditioned fear stress on serotonin neurotransmission and freezing behavior in rats. Eur J Pharmacol 28:23–30.

Hetrick, S. E., Purcell, R., Garner, B., & Parslow, R. (2010). Combined pharmacotherapy and psychological therapies for posttraumatic stress disorder (PTSD). *The Cochrane database of systematic reviews*, *7*, CD007316.

Khan S, Liberzon I. 2004. Topiramate attenuates exaggerated acoustic startle in an animal model of PTSD. *Psychopharmacology (Berl)* 172: 225–229.

Lattal KM, Barrett RM, Wood MA (2007) Systemic or intrahippocampal delivery of histone deacetylase inhibitors facilitates fear extinction. Behav Neurosci 121:1125–1131. doi:10.1037/0735-7044.121.5.1125

Matsumoto, Y., Morinobu, S., Yamamoto, S., Matsumoto, T., Takei, S., Fujita, Y., & Yamawaki, S. (2013). Vorinostat ameliorates impaired fear extinction possibly via the hippocampal NMDA-CaMKII pathway in an animal model of posttraumatic stress disorder. *Psychopharmacology*, *1*, 51–62.

Sharpless, B. A., & Barber, J. P. (2011). A clinician's guide to PTSD treatments for returning veterans. *Professional Psychology: Research And Practice*, 42(1), 8-15. doi:10.1037/a0022351

Sonne, C., Carlsson, J., Elklit, A., Mortensen, E. L., & EkstrÃ, m, M. (2013). Treatment of traumatized refugees with sertraline versus venlafaxine in combination with psychotherapy - study protocol for a randomized clinical trial. *Trials*, 137.

Takahashi, T., Morinobu, S., Iwamoto, Y., & Yamawaki, S. (2006). Effect of PRX on enhanced contextual fear induced by single prolonged stress in rats. *Psychopharmacology*, *2*, 165–173.

"PTSD: National Center for PTSD." *Apologies: Page Not Found* -. N.p., n.d. Web. 1 Aug. 2014. <a href="http://www.ptsd.va.gov/public/PTSD-overview/basics/how-common-is-ptsd.aspFind">http://www.ptsd.va.gov/public/PTSD-overview/basics/how-common-is-ptsd.aspFind</a>

Yamamoto, S., Morinobu, S., Takei, S., Fuchikami, M., Matsuki, A., Yamawaki, S., & Liberzon, I. (2009). Single prolonged stress: toward an animal model of posttraumatic stress disorder. *Depression and anxiety*, *12*, 1110–1117.

#### ACKNOWLEDGMENTS

I would like to give a special thanks to Dr. Shane Perrine for allowing me to work under his supervision with all the other researchers for their assistance.

# FOR THE BETTERMENT OF THE RACE: THE EFFORTS OF THE DETROIT URBAN LEAGUE IN ASSIMILATING BLACKS DURING THE EARLY GREAT MIGRATION, 1916-1917

By Andre Gilford, Jr. Major: History Mentor: Dr. David Goldberg, Department of Africana Studies

The Great Migration was a pivotal era in African American, urban, labor, and social history. Between the years of 1915 and 1920, thousands of African Americans living in rural and urban areas in the South migrated to Northern cities, increasing their populations and altering race relations very quickly. Historian Neil McMillen argued, "the story of the Great migration is among the most dramatic and compelling in all chapters of American history." These African American families left the South for a myriad of reasons. Some left due to the constant racial violence and discrimination that continued to escalate during this time. Others left to explore the allure of the "big city," northern life that they learned about through family members and friends. All, however, left in hopes of finding a better quality of life for themselves.

The promise of higher paying jobs made the move very alluring to struggling and poor African American families, many of whom were mired in debt peonage due to the predominance of sharecropping in the South. African Americans families desperately sought employment at companies paying \$5 a day like Ford Motor Company as a means to achieve the promise of the American Dream. However, once in the cities, these droves of poor and rural families were extremely challenged when making the trasition "from plantation to ghetto." Migrants were met with structural racism in Northern cities that limited African American families to crowdedness and predominantly African American areas where the quality of life was very poor. Employment was scarce as many of these migrants were denied entrance to most jobs due to race, or lacked the skills or experience increasingly expected in factory and domestic service work. The high cost of living and inflated rents within the Black communities led to crowdedness, unclean homes, unsafe environments, and increased risk of death and disease. The economic hardships faced by Black families, in turn, led to substantial increase in crime, infant mortality, and health crises. The dream of a better life in the big city was thus short-lived for many migrants as they strenuously fought to survive this climate of instability. City services and government were neither prepared nor inclined to offer assistance to the growing amount of Southern African American migrants. As a result, much of the community went under or un-serviced, and was drawn to find other means of survival. In Detroit, one limited, but saving grace for the plight affecting African American families was the Detroit Urban League. I argue that the Detroit Urban League, while limited in effectiveness due to white racism and their own class bias, nonetheless helped buttress African American migrant families as they struggles to deal with social, economic and racial conditions in their newfound homes, and did so by focusing its efforts on empowering African American families.

Throughout the course of this essay, I will explore some of the various ways the Detroit Urban League assisted with the transitioning of migrant African American families during its early years and the beginnings of the First Great Migration in Detroit. In this endeavor, I use archival information from the Detroit Urban League Papers of the Michigan Historical Collection held at the University of Michigan. These papers help understand the innerworking of the organization, including Executive Secretary reports, commentary, printed articles, surveys, and letters. Much of the documents show the complexities of the work of the Detroit Urban League and how they rose to the challenge of social-work by focusing on African American migrant families. To buttress my argument, I document and analyze a number of their relationships with African American migrant families

<sup>&</sup>lt;sup>1</sup> August Rudwick Elliott M. Meier, From Plantation to Ghetto (New York: Hill and Wang, 1976).

between the years of 1915 and 1917 and their struggles in Detroit. Using supporting literature to contextualize both the national migration of African American families and the Detroit migration specifically between these years, I explore both the triumphs and limitations of the work of the Detroit Urban League in relation to the Detroit poor African American families in its' early period.

The Great Migration caused a substantial increase in population in Northern cities without the governmental and social service infrastructure to support it. Between the years 1910 and 1920, the Black population in Detroit increased 611.3%, from 465,766 to 993,678.<sup>2</sup> African American migrants were generally from rural areas in what is considered the Black Belt states of Alabama, Georgia, Florida, Arkansas and Mississippi. The notion of the urban North as the Promised Land incited biblical narratives of the "flight out of Egypt and going to Canaan."<sup>3</sup> The migration fostered a self-sufficiency to find something better for them that many had not been able to experience. The migration exemplified the striving to the American Dream and to make for them a better life.

The surge of people aided in the industrial building of Detroit at the turn of the century. The mass numbers of African American families coming to Detroit contributed to the manpower of native Black Detroit families in growing substantial and progressive communities to fight for the political rights that they needed so desperately. Prior to the Migration, Black families in Detroit found themselves losing political and social ground as a result of the large immigrant population. The decision of southern Black families deciding to move to Northern cities like Detroit had a positive effect on the building of a major metropolis like Detroit, thus benefiting the larger Black communities. Author Richard W. Thomas argued, "Had southern black workers decided not to migrate—as indeed they could well have done, since many of their brethren did remain in the South—northern black communities would have stagnated."<sup>4</sup>

It is important to note the demographics of the African American migration to Detroit. Richard Thomas posits that the major push for migration occurred as a result of the demand for African American labor. African Americans needed jobs and came to the North primarily for that purpose. The labor market caused two major migration waves: 1916-1917 as result for labor demand and 1924-25 as a result of the increased strict immigration policies on the labor market.<sup>5</sup> African Americans were highly sought after by recruiters from many companies such as Ford Motor Company who would come to the South employing African Americans— primarily men—to come to the North for work Migrants decided to make the move North, due primarily to employment. For many migrants, if they could not find a job, they typically would leave for another opportunity elsewhere. This is proven in the fact that during the 1920-1921 recession, 17,000 Black workers unemployed in Detroit as new migrants left the city to go to other northern cities or back South.<sup>6</sup>

African American males were, generally, the first to come to Detroit in large numbers. Then, in 1917, African American women and children began to come to the city. However the employment status of work for the African American men were low as wages in the factory were not high enough to sustain the families' cost of living in the urban city. As a result, most of the migrant women who came to Detroit were employed in domestic service to aid in the support of the household.<sup>7</sup> Often, the women held more steady employment than the men and as a result caused much strain on the family. A more detailed account of employment and family will be explored later.

The issues concerning migrant populations were not atypical in Detroit. Many Northern urban cities experienced exponential growth as a result of the Great Migration. And generally, cities were not prepared or willing to

<sup>5</sup> Ibid., 27

<sup>6</sup> Ibid., 27

<sup>7</sup> Ibid., 58

<sup>&</sup>lt;sup>2</sup> Richard Walter Thomas, *Life for Us Is What We Make It: Building Black Community in Detroit, 1915-1945* (Bloomington: Indiana University Press, 1992).

<sup>&</sup>lt;sup>3</sup> George W. Grohn, *The Black Migration: The Journey to Urban America* (New York: Weybright and Talley, 1972).

<sup>&</sup>lt;sup>4</sup> Thomas, Life for Us Is What We Make It: Building Black Community in Detroit, 1915-1945.

accommodate Black migrants. As a result, the League on Urban Conditions Among Negroes was formed later to be called the National Urban League. The growing issues in Detroit called for a branch of the Urban League to be organized in the city. White philanthropists and benefactors came together from the Associated Charities of Detroit to find a solution to the rising issues concerning Black migrants. Eugene Knickle Jones, then the Executive Secretary of the National Urban League, sent correspondence to the Associated Charities of Detroit in 1915 promoting the idea of establishing a Detroit branch of the Urban League. The following year the branch was established with financial support from the Associated Charities of Detroit, a predominantly White organization. Forrester Washington—who at the time was working as a social worker at the national office of the Urban League in New York—came to Detroit to serve as its first director and bring much hope and expertise.

That same year, Washington sent out a letter to employers and social institutions of the city on behalf of the Associated Charities of Detroit trying to assess the status of Negroes in the mainstream Detroit community and "acquaint the colored people in Detroit with the social service agencies available to them."<sup>8</sup> Washington sought to address the issues of the African American migrant community by forming alliances with the social service agencies available to Detroit residents. Washington asked these employers how many black and white employees they had with the help of Boyd Fisher, who served as a representative of the Detroit Board of Commerce and on the board of Associated Charities Detroit. The results from the questionnaire showed that most employers did not employ Black people. If they did employ Black people, they would be minimal in number or occupy cleaning or low-skill occupations. One employer mentioned that "the conditions of our factory are not favorable for this class of help."<sup>9</sup> Washington's push for alliances with the white philanthropic and business society would prove to be pivotal in the buttressing of African American migrant families in Detroit during this period, however he and the DUL would not be exempt from racial discrimination.

Before the first joint committee meeting was held for the Detroit League in July 7, 1916, Washington compiled a report with necessary information to drive the efforts of the League for the upcoming year. He sought out to visit "the original sources, however high or exclusive, or difficult to approach . . . ascertaining their feelings thereto."<sup>10</sup> In this effort, he sent a letter to Mr. Chadsey, the superintendent of the public schools to find out the number and the conditions of African American children; and approached Mr. Dickerson and Mr. McGill<sup>11</sup> who was a part of the Probation Department of the Police Court as to how they would meet the droves of African Americans migrants coming to the city. The report that was drawn from this information was presented to the Board of Directors for the Detroit League in order to survey the issues among Black migrants. To this end, Washington would provide a necessary framework around the conditions of African American migrants to assimilate into Detroit.<sup>12</sup>

Washington understood the urgency of the situation in Detroit. Families were in the middle of huge shifts as every day, hundreds of southern Blacks migrated to Detroit for a better life. Washington lamented, "Nothing is being done in the way of adjusting these colored strangers to their new environment and assimilating them healthfully. Hence, a situation is being created which, unless proper preventive measures are soon taken, will present a very difficult problem in the not too distant future."<sup>13</sup> It was a desperate situation for many migrants seeking refuge from the dire circumstances of the South and finding no comfort in Northern cities like Detroit.

<sup>12</sup> Washington, "Report for June 1916."

<sup>&</sup>lt;sup>8</sup> Forrester Washington, "Letter to Rev. John Meiser, German Protestant Home for Orphans," in *Detroit Urban League Papers* (Michigan Historical Collections, 1917).

<sup>&</sup>lt;sup>9</sup> Robert Brass Company, "Letter in Response to Boyd Fisher, Detroit Board of Commerice," in *Detroit Urban League Papers Microfilm*, ed. Michigan Historical Collections (Bentley Historical Library, 1916).

<sup>&</sup>lt;sup>10</sup> Forrester B. Washington, "Report for June 1916," in *Detroit Urban League Papers*, ed. Michigan Historical Collections (Bentley Historical Library, 1916).

<sup>&</sup>lt;sup>11</sup> The archival document, "Report for June 1916" mentions these individuals as written, without a first name.

<sup>&</sup>lt;sup>13</sup> "Report of Director, October 16, 1916," in *United Community Services Collection*, ed. Wayne State University (Walter Reuther Library, Archives of Labor and Urban Affairs).

Among many of the problems were the negro death rate which was twice as high than the whites; the lack of boarding homes and 'decent' places to live were hard to find for Negro children; and that "Negroes were found in the most unskilled and unhealthful conditions."<sup>14</sup> The charge was clear for Washington that the Detroit League for Urban Conditions Among Negroes was to address the gap of services for African American migrants in Detroit and meet their needs. As mentioned prior, he understood the importance of appealing to the city's resources which were predominantly white to support the hundreds of new individuals and families he met every day.

In the beginning stages of the DUL, the work to be done had increased to massive heights for its small staff and poor funding to address it all. Richard Thomas notes that the, "The Detroit Urban League had only three people on its staff to address the problems of finding jobs and homes for thousands of uprooted and disoriented black rural peasants." <sup>15</sup> The Detroit Black migrant population was exactly unfamiliar rural people in a new area with much allure that could potentially harm their success in the city. It had to be a priority of the DUL to mold these former sharecroppers with obviously rural tendencies to become urbanized working-class citizens of Detroit. To the DUL, "job placement was the best strategy for black community building." As a result, the DUL primarily became a job placement organization.

Washington became noted for his substantial push for job placement. He was well known for believing "jobs as the foundation of all black social and economic development."<sup>16</sup> In this regard, Washington understood that the many Black families coming to Detroit during that time sought better living conditions more than anything. His later research would prove this point.<sup>17</sup> In order to deal with the major requests of employment coming from migrants, Washington instituted an employment secretary who dealt solely with employment and whose salary was paid by the local Employment Association. The alliances between the Urban League and the white employers became highly successful in sustaining the Black community through jobs and other resources.

For Washington, race betterment was directly correlated with efficiency. It was his priority to turn these migrant Blacks into 'efficient' citizens. In a speech to the St. Mark's Brotherhood at Bethel African Methodist Episcopal Church, he spoke about the need to build efficiency within the Negro in order for the White employers to see the Negro as an invaluable asset to the workplace before and after the Great War. Efficiency in his words was "the quality of producing results . . . delivering the good . . . [and] amount of useful work from energy goods."<sup>18</sup> He believed "the country needs the Negro now as it never needed them before. He is needed in industry. For once man power is more important than capital . . . Now is the time that the Negro should take advantage of the education in efficiency that was denied him before and really develop power."<sup>19</sup> Washington believed that it was in the best interest of the Negro to assimilate to the values and tendencies of the White employers in order to find sustainability. He believed that in efficiency, African American migrants could finally advance to a more comfortable standard of living. It could be said that Washington did not understand that these Negro migrants had come from hard labor in the South working plantations and cotton fields under harsh sharecropping environments. However, such was his hope in efficiency that he believed that, "if the community can be convinced that the Negro is and always will be a business asset, we needn't worry much about housing, employment and recreation."20 Washington was willing to place all his efforts in assimilating the African American migrants in order to make them invaluable to the workplace. It could be said that Washington was a bit naïve to the racial discrimination prevalent in Northern cities, like Detroit, that he places the most

<sup>14</sup> Ibid.

<sup>15</sup> Ibid., 54-55

<sup>16</sup> Thomas, Life for Us Is What We Make It: Building Black Community in Detroit, 1915-1945., 55

<sup>17</sup> Please refer to his entire official survey completed while he was working for the Associated Charities of Detroit: Forrester B. Washington, *The Negro in Detroit: A Survey of the Conditions of a Negro Group in a Northern Industrial Center During the War Prosperity Period* (Nabu Public Domain Reprints, 2012).

<sup>18</sup> Forrester Washington, "Efficiency Speech Given at St. Mark's Brotherhood, May 20, 1917," in *Detroit Urban League Papers*, ed. Michigan Historical Collections (Bentley Historical Library).

<sup>19</sup> Ibid.

<sup>20</sup> Ibid.

responsibility on Black migrants for their advancement rather than critiquing structural racial inequities. For Washington, this could honestly be seen as a necessary strategy to get these Black migrants into work.<sup>21</sup>

When he sent out Black migrant workers to jobs, Washington made sure to emphasize his efficiency rhetoric by charging them to be "punctual, zealous and ambitious" in their work.<sup>22</sup> Of course, this played into his belief that they needed to prove themselves in order to create trust and reliability by their white employers. To achieve this end, the League set up the Young Negro Progressive Association made up of young black college men. These men would go and visit the employees during their one-hour lunch breaks to talk with the migrants about what to do on the job and provide tips on good work habits.

Washington's class bias of race betterment often persuaded him in his efforts to aid the migrants, especially according to dress. He made an effort to transform the appearance of the migrants to meet the expectations of white employers. The dress of women with "calico mother hubbard" headwear and the young men who dressed in "overalls and undershirts" disturbed Washington.<sup>23</sup> However, he made it known that this efforts were not purely bias, but a keen understand that "Whites are the judges and blacks are being judged."<sup>24</sup>

The League's focus on employment for the migrants in Detroit was based in sincere ideas of how to create strong families and communities. Across the country, employment of African American migrants was a problem for the families. It was a common tendency for African American men to leave their families in the South in order to find work in the North. However, the tendency for Black men to find consistent and stable jobs caused much more "reliance on women" because they "found it much easier to get work as domestic servants in white households."<sup>25</sup> This would inadvertently place strain on relationships and families causing much desertion of Black men from families due to the assumption that he could not provide for his family. What the Detroit Urban League did in its early days in response to the "roving masses of Negro men" was a great and successful experiment to somewhat alleviate these issues with the family, although not entirely.<sup>26</sup>

In line with the efficiency rhetoric, Washington implemented many initiatives in order to assimilate the Negro and enforce the good impressions necessary for access to white resources. These good impressions meant dressing and acting how Whites expected them to act. To this degree, the League published a pamphlet which sought to underscore this effort. In the pamphlet, the League promoted "helpful hints" to the African American migrants orienting them to the lifestyle that was essential to success in the urban center, including good hygiene, punctuality, proper dress both at the workplace and at home, and many others. Phrases like, "Don't spend all your money for pleasure. Save some of it for extra clothing and fuel for the winter and to take care of your family and yourself when sickness comes," on one hand made a lot of sense in that many of the migrants would make more money than they would ever dream of, but on the other hand perpetuated the middle class values from the staff of the League like Mr. Washington.<sup>27</sup> Further, the League made it clear that if these "helpful hints" are not taken into practice, "this kind of carelessness will lead to discrimination and segregation."<sup>28</sup> Because "whites were the judges and Blacks were being judged,"<sup>29</sup> the League wanted to ensure that the best

<sup>&</sup>lt;sup>21</sup> Ibid.

<sup>&</sup>lt;sup>22</sup> Thomas, Life for Us Is What We Make It: Building Black Community in Detroit, 1915-1945., 55

<sup>&</sup>lt;sup>23</sup> Washington, "Report of Director, October 16, 1916."

<sup>&</sup>lt;sup>24</sup> Forrester Washington, "A Program of Work for the Assimilation of Negro Migrants in Northern Cities," in *Detroit Urban League Papers Microfilm Edition*, ed. Michigan Historical Collection (Bentley Historical Library, 1917).

<sup>&</sup>lt;sup>25</sup> Donna L. Franklin, *Ensuring Inequality: The Structural Transformation of the African-American Family* (New York: Oxford University Press (US), 1997).

<sup>&</sup>lt;sup>26</sup> Ibid.

 <sup>&</sup>lt;sup>27</sup> The League on Urban Conditions Among Negroes, "Helpful Hints," in *Detroit Urban League Papers Microfilm Edition*, ed. Michigan Historical Collections (Bentley Historical Library, 1917).
<sup>28</sup> Ibid.

<sup>&</sup>lt;sup>29</sup> Forrester Washington, "A Program of Work for the Assimilation of Negro Migrants in Northern Cities,"ibid., ed. Michigan Historical Collection.

impression is made on Whites by Blacks, not only to survive, but to ensure racial advancement and progress is made in every sector of the Black community. Otherwise, the League's reliance and alliance with White employers and city services could be in jeopardy, ultimately causing great harm to the Black community, especially the vulnerable migrants. These initiatives became important to helping to ensure the efficiency of the Negro migrants in a new territory like Detroit.

The tasks of the League were multifaceted. Outside of working to make sure the Negro migrants were employed, housed, and efficiently assimilating into the culture of the urban core, Washington and his staff became the first responders to economic and social issues facing the Black community. In 1917, there were very little Negro organizations capable or willing to take on the task of adjusting and aiding the migrant community. The League took on the responsibility of ensuring that employment, housing, recreation, crime, cooperation and efficiency were prioritize and addressed in the Negro migrant community. The League took seriously the importance of addressing the needs of the Negro migrant community.

By the end of his first year, Forrester Washington had implemented a vocational bureau focused on employment for the Negro migrants, coerced "two of the largest foundries in the city to build housing for its workers,"<sup>30</sup> implemented a community dance held every Tuesday, athletic opportunities every Saturday, persuaded the Police Commissioner to designate a Negro police officer in the Black community to suppress crime and established a working relationship with the Board of Commerce and the Employers' Association in order to improve the working conditions of Negroes. All of these initiatives led to the buttressing of the African American migrant family during the early Great Migrations in Detroit. Washington's work with the League in Detroit became a model of how to efficiently handle the Negro migrant community and he was called on to speak on it constantly.

The work of the Detroit League on Conditions Among Negroes came to be known as the Detroit Urban League. After Washington left for a new position with the federal government, John Dancy replaced him as Executive Director. Dancy continued the work of Washington maintaining a focus on employment as a means to sustaining black families. Dancy, also focused on other areas in the black community such as social and recreational entities in order to build strong families. The establishment of the Columbia Center which included a baby clinic offering assistance to mothers and their children proved to be a great way to build strong families. Weekly dances became a common meeting place for Black migrants to release the stress of work. What the DUL evolved into was a one-stop shop for Black families. The betterment of the race was done through sustaining black migrant families, which the Detroit Urban League did successfully. Although the class biases of the leadership pervaded the efforts of the League, it was highly successful in the development of black migrants into black industrial workers and providing the foundation for strong black urban families.

#### BIBLIOGRAPHY

Company, Robert Brass. "Letter in Response to Boyd Fisher, Detroit Board of Commerice." In *Detroit Urban League Papers Microfilm*, edited by Michigan Historical Collections: Bentley Historical Library, 1916.

Franklin, Donna L. *Ensuring Inequality: The Structural Transformation of the African-American Family.* New York: Oxford University Press (US), 1997.

Grohn, George W. *The Black Migration: The Journey to Urban America*. New York: Weybright and Talley, 1972.

Meier, August Rudwick Elliott M. From Plantation to Ghetto [in English]. New York: Hill and Wang, 1976.

Negroes, The League on Urban Conditions Among. "Helpful Hints." In *Detroit Urban League Papers Microfilm Edition*, edited by Michigan Historical Collections: Bentley Historical Library, 1917.

Thomas, Richard Walter. *Life for Us Is What We Make It: Building Black Community in Detroit, 1915-1945.* Bloomington: Indiana University Press, 1992.

Washington, Forrester. "Efficiency Speech Given at St. Mark's Brotherhood, May 20, 1917." In *Detroit Urban League Papers*, edited by Michigan Historical Collections: Bentley Historical Library.

———. "Letter to Rev. John Meiser, German Protestant Home for Orphans." In *Detroit Urban League Papers*: Michigan Historical Collections, 1917.

———. "A Program of Work for the Assimilation of Negro Migrants in Northern Cities." In *Detroit Urban League Papers Microfilm Edition*, edited by Michigan Historical Collection: Bentley Historical Library, 1917.

Washington, Forrester B. *The Negro in Detroit: A Survey of the Conditions of a Negro Group in a Northern Industrial Center During the War Prosperity Period*. Nabu Public Domain Reprints, 2012.

———. "Report for June 1916." In *Detroit Urban League Papers*, edited by Michigan Historical Collections: Bentley Historical Library, 1916.

———. "Report of Director, October 16, 1916." In *United Community Services Collection*, edited by Wayne State University: Walter Reuther Library, Archives of Labor and Urban Affairs.
# THE BENEFITS OF PLUG-IN – HYBRID AND ELECTRIC VEHICLES ON THE ECONOMY AND THE ENVIRONMENT.

By Greg Gillette Major: Engineering Technology Mentor: Dr. Yeau-Jian Liao, Engineering Technology Division, College of Engineering

#### ABSTRACT

This paper analyze the cost effectiveness of the Plug-in Hybrid Electric Vehicle (PHEV) and the Electric Vehicle (EV). It also explored the environmental benefits of PHEV and EV vehicles by the use of statistical data from the Department of Transportation, Environmental Protection Agency. A survey will be conducted to determine the average weekly commute (miles), weekly fuel cost (gallons) and preferred fuel grade. The survey also polled questions that looked into likability of purchasing an EV versus a PHEV. The resulting information will be used to compute the annual saving to the consumer for not using fuel and to gauge the consumer appeal of the two vehicles. This assessment also includes the impact that these types of vehicles have on the environment as it relates to reducing the carbon foot print made from Carbon Oxide gas emissions. In addition, this analysis also reveals the economic benefit that this new technology has created.

The recent rise in efforts to keep the environment clean and protected has called for the many industries and Americans to do their part in the reducing of the carbon foot print made from carbon oxide emissions. There are two main categories that largely make up all carbon oxide emissions. These categories are named indirect and direct emissions.

Indirect carbon emissions are the type of emissions caused by the burning of fossil fuels to make products, materials and services by industry. The reduction of this type of emissions can only be done by the industrial communities.

Many industries have been trying to redesign themselves to comply with EPA standards. In order to comply with governmental demands they must employ different manufacturing strategies, methods of recycling and technologies to help reduce their carbon footprint. For example, a bottling company that would create plastic bottles from raw material can change its manufacturing strategy to now use recycled plastic to create new bottling more efficiently. An illustration of a recycling method is the State of Michigan has refundable bottles and cans in hopes that the consumer would use it as an incentive to return the container for recycling. In the case of Jet Ink printer manufacturers, they were able to create a Jet ink cartridge that can be reusable by using technologies to refill the cartridge. The same efforts are expected for the US automobile industries.

Direct carbon emissions are caused by households in America; this is largely due to household heating and the use of automobiles. In fact, the greatest contributor to US household emission is due to transportation. A major portion of the U.S. transportation sector is powered by fossil fuels. With the understanding of the role US households have in creating carbon emission, it is important that households join in the fight with industry against carbon oxide emission into the environment. Many communities have been trying to reinvent the way certain practices are done in order to reduce their effect on the environment. Individuals have also been making different life choices in an attempt to comply with the "Going green" concept. Although households and industries create carbon emissions differently, the method to reduce CO2 emissions is the same. The method can be referred to as the 3R's. The 3R's is an abbreviation that means Reduce, Reuse and Recycle. Both industry

and households can reduce carbon emission by the conserving energy (Reduce), purchasing products that are reusable (Reuse) and by participating in a local recycling program (Recycle).

Similar to the environment, the economy is very important to US government and its citizens. The economy is affected by many factors. One of these factors is due to the nation's transportation sector's need for fossil fuels. Fossil fuels contain high percentages of <u>carbon</u> and include <u>coal</u>, <u>petroleum</u>, and <u>natural gas</u>. The US economic status can be directly influenced by fluctuating cost of <u>petroleum</u>. For example, if the price of gasoline goes up, the financial burden felt by US families increases. This could cause a rippling effect that hurts consumer confidence and pushes the economy in a negative direction. A robust economy produces employment, small business creation and more retail purchasing. Consequently, the need for a strong economy is very important. Although the recent rise in awareness for eco-friendly practices is extremely important, the same team effort is needed by government, industries and citizens to promote economic growth.

This paper will explore the impact that EV and PHEV vehicles have on the economy and environment. In addition, this paper will illustrate the unique way these vehicles help government, industry and households achieve the common goals of reducing CO2 emissions and promoting economic prosperity.

# LITERATURE REVIEW

My interest is to conduct research exploring the economic and environmental benefits of hybrid vehicles using a mix method research approach. I will employ the mix method approach in order to quantify the consumer economic and environment benefits and to qualify consumer likeability for hybrid vehicles. The quantitative portion of my research will analyze statistical data in order to prove hybrid's economic and environmental benefits. The qualitative portion of my research will be done by conducting a survey to determine the likeability of hybrid vehicles by Metro Detroiters.

In order to gauge the state of the art opinion for the effects that hybrid vehicles have on the economy and the environment, I constructed a literature review. The literature review will analyze the different research questions, methodologies and commonality in their results.

#### EMISSIONS IMPACTS OF PLUG-IN HYBRID ELECTRIC VEHICLE DEPLOYMENT ON THE U.S. WESTERN GRID

Jansen, Brown and Samuelsen (2010) and I research both have concerns for the hybrid vehicle's environmental impact. It is my intent to investigate whether hybrid vehicles have an eco-friendly characteristic. In their research they modeled the carbon emission produced from the U.S. western power grid caused by charging hybrid fleets. Their research revealed that carbon emission created from the charging the hybrid fleet would be insignificant providing charging is done during off-peak time.

The author's point of view was to make a real world model of the Western grid. They were particularly concerned with modeling the grid's capacity to handle fleet of charging hybrid vehicles. In addition to modeling grid capacity, their focus was also on modeling the amount of carbon emission that would be produced from the power grid. Thus creating a charging profile that can be used to institute charging practices in the future.

According to the authors, their methodology was unique, because it used historical data instead of the normally used production cost data to create the distribution profile. The authors claimed this made their model more "real world". Their belief was in order to have a real world model, cost production data would not be as useful. According to the authors, cost production data excludes black outs, harsh weather and etc. In my opinion their method is different compared to the case studies that use statistical data, because their method uses historical data which will take into account a more realistic depiction of past energy distribution and carbon emissions.

#### EXPERIMENTAL EVALUATION OF HYBRID VEHICLE FUEL ECONOMY AND POLLUTANT EMISSIONS OVER REAL-WORLD SIMULATION DRIVING CYCLES

The work done by Fontaras, Panayotis and Samaras (2008) relates directly to my research interest, but has a slightly different purpose. The theme of the authors was to explore the fuel economy and the air pollution of a hybrid vehicle. Which is very similar to my research, because my focus is economic and environmental effects of hybrid vehicles. In my research, I will attempt to quantify the economic benefits that hybrid vehicles provide to the consumer and that they are more environmentally friendly than conventional vehicles.

The Authors primary concerns were to construct a model that could be used for evaluating the amount of carbon emitted and fuel efficiency of the Pirus II and the Honda Civic IMA. Hybrid vehicles compared to conventional vehicles. Their methodology used two different simulation drive cycles which includes the Artemis real world drive cycle and the New European Drive cycle. The model also used real world driving data. They examined the performance of the hybrid at high and low speeds in order to simulate highway and urban driving conditions. (Fontaras, Panayotis and Samaras, 2008).

The authors view point can be expressed through the main focus of their research. First, their research was concerned with the analyzing two different hybrid vehicles for their fuel efficiency and their carbon emissions compared to conventional vehicles. The authors also explored the effects that temperature has on fuel economy and carbon emission. (Fontaras, Panayotis and Samaras, 2008). Their overall aim was to simulate various conditions that illustrate the fuel economy and the environmental benefits of hybrid vehicles. Their results concluded that hybrids do reduce air pollution in the forms carbon emissions and that they provide their maximum benefit in urban driving conditions.

#### ENVIRONMENTAL AND ENERGY IMPLICATION OF PLUG-IN-HYBRID-ELECTRIC VEHICLES

The research of the Authors of Craig H. Stephan and John Sullivan relates to my interest, because we both have an interest in the environmental benefits to Plug-in-Hybrid-Electric Vehicles. Similarly, they were able to do an analysis of statistical data to determine the carbon emission reduction benefits to hybrid vehicles. (Craig H. Stephan and John Sullivan, 2007).

The two main focuses of their research was to explore the implications that Plug-in-Hybrid Vehicles have on the environment and the demand they place on U.S. energy. (Craig H. Stephan and John Sullivan, 2007). Their concerns were to also determine if it was feasible to replace old power plant infrastructure with new more efficient power plants or replace conventional vehicles with hybrid vehicles and to also determine if the present capacity of energy production would be enough to charge a hybrid fleets throughout America. (Craig H. Stephan and John Sullivan, 2007).

The views of the authors were to look into the charging scenarios of hybrids. This is done in order to determine if the present power infrastructure has the capacity needed to recharge several Hybrid vehicles. Their results yielded that the present infrastructure could handle the energy capacity needed for charging several hybrid vehicles provided if charging was done at night. (Craig H. Stephan and John Sullivan, 2007). They also concluded to determine whether or not to replace old power plants on old conventional vehicles, would critically depend on the fuel economy of the vehicle being replaced. (Craig H. Stephan and John Sullivan, 2007). The methodology view point of Craig H. Stephan and John Sullivan (2007) relates to my interest, because I will also explore the possible effects carbon emissions has on the environment via statistical data.

# TECHNO-ECONOMIC ANALYSIS AND DECISION MAKING FOR PHEV BENEFITS TO SOCIETY, CONSUMERS, POLICYMAKERS AND AUTOMAKERS

The research of Baha Mohammed Al-Alawi relates to my research, because of our similar interest to quantify the consumer benefits of hybrid vehicles. The author created a model that he entitled "Total Cost of Ownership". Baha Mohammed Al- Alawi's model takes into account the variables of ownership. (Baha Mohammed Al- Alawi, 2012). Baha Mohammed Al- Alawi and I find interest in the exploration of Hybrid's consumer benefits. Baha Mohammed Al- Alawi (2012) explains the importance of the "Total Cost of Ownership" model is to simulate and quantify the consumer benefits.

Baha Mohammed Al- Alawi's (2012) main focus was to build a multi-model that would simulate the benefits of hybrid vehicles for various benefactors. Baha Mohammed Al- Alawi believed his research was novel, because he explored the possibilities of creating a model that could simulate and optimize the benefits of hybrid vehicle for automakers, consumers and policy makers. (Baha Mohammed Al- Alawi, 2012). The automakers model was constructed to simulate fleet fuel economy and CAFÉ standards compliance. CAFE standards are the fleet fuel economy that U.S. automakers must adhere to or pay fines that are enforced by the U.S. government. The consumer model is referred to by the author as the "Total Cost Ownership" model. This model consisted of several ownership parameters such as car loans, insurance and maintenance in order to depict all factors of vehicle ownership and compare results to conventional vehicles. (Baha Mohammed Al- Alawi, 2012). Baha Mohammed Al- Alawi (2012) states, that he did an analysis of a literature review to predict and model the market penetration of hybrid vehicles. Finally, Baha Mohammed Al- Alawi, (2012) built a model based on the contributions of the other models in order to illustrate benefit to automakers, consumers and policy makers.

Baha Mohammed Al- Alawi (2012) makes his viewpoint apparent by the multi-model he constructed. Baha Mohammed Al- Alawi (2012) explained that this type of study consist of layers of modeling and had not been done for Plug-In- hybrids, but had been done for conventional vehicles. Baha Mohammed Al- Alawi (2012) aim of research was to create a model that illustrated benefits for multiple benefactors. (Baha Mohammed Al- Alawi, 2012).

#### EARTH TALK: ARE HYBRID VEHICLES REALLY BETTER FOR THE ENVIRONMENT?

In an article from the Chicano Weekly that responds to a question from one of its subscribers, about the economic and environmental benefits of a hybrid vehicle, the article and my research have the same central question. We both are attempting to illustrate the benefits of economic and environmental hybrid vehicles. In addition to having similar central ideas, we also share likeness in methodology. The use of statistical data to support the central idea is another commonality. The article uses statistical data to answer the question of the subscriber and I will use it to explore my research question.

The article's main focus was to answer the questions posed by a subscriber. The subscriber wanted to know the benefits of hybrid vehicle when compared to conventional vehicle. He also had an environmental concern. He wondered that if the driving sector converted to the use of hybrid vehicle, that the need to produce more electricity from a pollute source such as coal would increase. Thus, creating his second comparative question do the pros outweigh the cons as it relates to the environment. The article uses stats from the Electric Power Research Institute to illustrate economic benefit that hybrids have over conventional cars (El Chicano Weekly, 2009). The article also provided statistical data that supports the present infrastructure being adequate enough to charge large fleets.

The three main views that the article expressed were operation cost, carbon emissions comparisons between hybrids and gas powered cars and infrastructure capacity. These particular views were the articles approach to best answer the subscriber's questions. The subscriber's primary concern was the operation cost comparison and does the environment really benefit from the use of hybrids. The article presented statistics that validated

the superiority of hybrid over conventional cars and evidence of the present infrastructure's capability to recharge a significant amounts of hybrids (El Chicano Weekly, 2009).

COCA-COLA TRANSFORMS SERVICE VANS TO HYBRID VEHICLES.

The 'Going Green' campaign has made some industries change to more environment friendly practices. For example, Coca-Cola Inc. has begun to convert their service fleet to hybrid vehicles.

Cola-cola has created a program called "the drink in your hand", which is a commitment to a 25% reduction in their carbon footprint by 2020 (W. Garth Sr. 2014). The eco-friendly business model of Coca-Cola is apparent from a quote made by Bruce Karas, Vice President of Environment and Sustainability, "We continue to make energy-savings investments because they are good for business, good for the communities we serve and good for the plant" (W. Garth Sr. 2014). This article is highly relevant to my research, because it explores the economic and environmental benefits. Additionally the article provides a real world application of the positive contributions of hybrid vehicles.

Garth's article focuses on showcasing the benefits of hybrid vehicle technology brings to the owner and those whom implements the technology. He discusses the overall benefits that hybrids bring to their owners. In Garth's case study the owners are the Coca-Cola Company. Coca-Cola has consulted with XL Hybrids Inc. to implement hybrid vehicle technology to help with their carbon emission goals. XL Hybrids Inc. mission statement is to accelerate the fuel and emission reduction at a large scale (W. Garth Sr. 2014). Garth (2014) reports on the Coca-Cola Corporation findings after they converted to hybrid vehicle technology. Their findings reveal that converting to hybrid technology was greatly beneficial.

Garth (2014) main view point is to showcase an application of the benefits of hybrid vehicles. In the article Garth discussed the early success of the Coca-Cola's transformation. Garth (2014) is an advocate of the hybrid vehicle and their potential benefits. Garth (2014) used stats from Coca-Cola's case study to support his advocacy. The use of the case study data validated his view with real world data. Garth also used quotes from Coca-Cola executive to show the overall importance of eco-friendly practices are to large fleet service companies (W. Garth Sr. 2014).

# COMPARATIVE ANALYSIS OF THE LITERATURE REVIEW

The comparative analysis of the literature will group the literature into two methodology categories. The two groups are modeling and statistical data use. This comparative approach was chosen simply because literature reviewed used these two methodologies.

The modeling group consist of three pieces of literature. Although the literature in this group employs the same methodology approach, they have slightly different central questions. Jansen, Brown and Samuelsen (2014) and Fontaras, Panayotis and Samaras (2008) both have an environmental component to their central question. They have a common interest in trying to quantify carbon emissions. However they differ because they examine different products of carbon emissions. For example, Jansen, Brown and Samuelsen (2014) conducted an analysis of carbon emission caused by grid from recharging hybrids. Alternatively, Fontaras, Panayotis and Samaras (2008) did a carbon emissions comparison analysis of conventional vehicles to hybrid vehicles. The third piece of literature has a completely different focus. The dissertation of Baha Mohammeed Al-Alaw (2012) focuses on creating a model that quantifies the consumer benefits of hybrid vehicles. His approach was particularly interesting because it incorporates the effects of automakers, lawmakers and hybrid ownership.

The statistics group also consisted of three pieces of literature. Two pieces of the literature are articles and the other one is a research paper. All of the literature in this group uses the data analysis method to support their central question. The literature has a common theme of promoting the environmental benefits of hybrid vehicles.

The research paper of Craig H. Stephen and John Sullivan (2008) uses stats to illustrate the environmental benefits and focuses on the grid capacity which is similar to the literature of Jensen, Brown and Samuelsen (2008). Although the two pieces of literature have different methodologies, they yielded similar results. They both conclude that hybrid's carbon emissions are significantly lower than conventional vehicles. Another shared viewpoint in their results was that the present grid can recharge a large fleet of hybrid vehicles. They also agree that the best way to avoid grid capacity problems is to charge the vehicles at night.

The two articles in the statistical group promote the eco-friendliness of the hybrid, however they differ slightly in purpose. In the article from El Chicano Weekly, the author's purpose was to answer the subscriber questions about the benefits of hybrid vehicles. The other article from W. Garth Sr. explored the real world application of the use of hybrid technology. It showed the benefits received by the Coca-Cola Company as a result of converting of their services fleet to hybrid vehicles. Both of the articles concluded that the vehicles provide benefits to the environment and the owner.

#### LITERATURE REVIEW CONCLUSION

This literature reviews was done to provide me with an insight into the existing research and to motivate my contributions to the existing body of knowledge about hybrid vehicles. It was also the intent of the literature review to expose different methodologies. The exposure would allow me to examine varies methodologies and possibly help me find a novel approach to collecting data.

The literature chose for analysis provided a broad but clear assessment of the state of hybrid vehicle technology. The review was able to demonstrate the common problem that industry scholars focus to address. The review gave a clear understanding of the popular questions or doubts that consumers, lawmakers, auto makers and environmentalist have about the technology. One of the common questions for the hybrid vehicle industry is, can you quantify fuel economy and environmental benefits? Another frequently asked question of the industry is, does the present charging infrastructure have adequate charging capacity for large hybrid fleets? Although authors from the literature review were able to answer those concerns using different methods, their results were similar, suggesting that hybrid vehicles technology are an overall benefit to society.

A lot of the knowledge gained from the review will serve as validation in my research. The literature review helped me to create a thesis statement that relates to the concerns of the day. It assured me that my topic was relevant and aligned with other scholars who have similar interests. This was important because it defined my area of contribution. In order to make a novel contribution to the existing body of knowledge the literature review was critical. The literature review exposed different methodologies and validated the novelty of my contribution. Since the researchers of hybrid vehicle has to commonly defend their economic and environmental benefits, I thought the novelty of my contributions relied on my choice of methodology. For my research, I chose the mixed method approach. Out of the six pieces of literature only one used the mixed method research approach. Mixed methods was chosen because my research explores the likability of hybrid vehicles as well as the economic and environmental impacts.

The review served as a great starting point and tool for proceeding with my research. It helped me to determine my thesis topic and a novel methodology. Both thesis topic and novel methodologies are essential for scholarly contributions to the state of the art.

# METHODS

The theoretical frame work for my research was develop from the literature review on hybrid vehicle technology. The awareness of the prior hypothesis and methodologies directed my research efforts. The literature review influenced me to choice a relevant research question and method. In addition it expand the relevance of my research to explore the likability of hybrid vehicle technology. With this insight I discovered the criteria that my methods had to address. Two contributions in particular from the literature review had the most influence my theoretical framework.

The dissertation by Mohammed (2012) serviced as part of the theoretical framework for my methodology. Mohammed (2012) created a model that would qualitatively simulate the effects of hybrid vehicles on multiple stakeholders. Mohammed's (2012) constructed different models with the intent that they could be used for Automakers, lawmakers and consumers. Similarly, I will explore the consumer acceptance to hybrid vehicles.

The research of Fontaras, Pistikopoulos and Samaras (2008) also helped to form my theoretical framework. Their research used modeling to quantify fuel economy and carbon emissions. This is very similar to my research question, because I will analyze the fuel savings to quantify the consumer cost benefit. Additionally, my research will attempt to quantify the environmental benefits of hybrid vehicles.

Based upon the literature review contributions mentioned above having similar thesis topic to my thesis topic. The novelty in research would depend on uniqueness of my methodology. In order to address the dual components of my hypothesis, I have choose the mixed method approach. This approach will allow me explore the qualitative effects of fuel savings and emission reductions. The other component to my research needs to explore the consumer appeal of hybrid vehicles so the qualitative approach is required. According to John W. Creswell (2014) the embedded mix method is appropriate for method for my research, because data analysis and data collecting can happen during the same time frame.

Part of my methodology procedure is to conduct a survey of open and ended questions. The survey question will be distributed via survey monkey. The sample is 50 metro Detroit drivers that are asked a range of questions in order to gauge their driving range and fuel consumption habits of their daily commutes. The survey will also be used to determine the qualitative value of hybrid vehicles to the consumers. Statistical data will be used from the Department of Energy to determine the operating efficiency between a conventional vehicles versus a hybrid vehicles. Statistical data will also be used from EPA to quantify the overall carbon emissions created by the U.S. Transportation sector. The reduction of carbon emissions that hybrid vehicles provide is illustrated by the research of Stephan and Sullivan (2007). Additionally an operating cost comparison between the Chevy Volt and Chevy Impala in order to quantify the cost benefit of hybrid vehicles.

RESULTS

The survey question and answers of 50 Metro Detroit drivers

- Q1. What grade of fuel do you purchase?
- A1. 68.09% preferred Regular, 25.53% preferred Premium, 10.64% Middle grade
- Q2. What are your daily commute miles?
- A2. The average daily commute miles was 31.72 miles
- Q3. What is the amount of fuel dollars spent weekly? A3. \$79.02

Q4. Would you purchase an electric vehicle? A4. 42.22% No, 37.78% Yes, 20.00 Maybe

Q5. Would you purchase a hybrid vehicle? A5. 38.64% Yes, 31.82 Maybe, 29.55% No

# Environmental statistics

According to Environmental Protection Agency (2012) 82% of all U.S. greenhouse gases emission from human activities. The EPA (2012) also states, 32% percent of the of all greenhouse gas come from the transportation sector. The research of Stephen and Sullivan for Advance Engineering, Ford Motor Company (2007) abstract states, Plug-In hybrids vehicles produce 25% percent less emissions in the short term and 50% in the long term.

Their views were based on the premise old power plant infrastructure yields 25 % less emissions, but when the more efficient power plants are constructed 50 % reduction in carbon emission is possible.

# Comparison of Chevy volt (hybrid) and Chevy impala (conventional)

Statistical data was used from the fueleconomy.gov to determine the efficiency of both of the vehicles. Additional statistics were used from the survey establishing the preferred fuel cost and annual commute mileage that will be used for calculation in the comparison.

The Chevy Volt emits less carbon dioxide than the Chevy Impala. The Chevy volt also provide the average annual commute fuel savings of \$1617.00. However, the Chevy volt cost \$11,800 more than the Chevy impala. So despite the savings the breakeven point is 7.3 years away.

# DISCUSSION

In this section I will discuss the limitations and future development of my research. The sample size was definitely a limitation to the scope of my research. If the sample size were lager the results would reflect a truer depiction of the U.S. transportation sector. Resources was another limitation to this research. If more resources were available actual experiments could have been conducted, instead of the use of statistical data to validate the benefits of hybrid vehicles. One example, would be to perform a carbon emission comparison between a conventional vehicle and a hybrid vehicle.

The future development of this research will continued and expanded in a Master's thesis. Hybrid technology will remain as the general focus, but quantitative methodology will be used. The central focus of the new research will explore a particular components in the hybrid architecture. The components of interest are the powertrain (integration between the electric motor and the combustion engine) and the power electronics. The purpose of this research would be to gain a theoretical understanding of the components and construct a real small scale version. Additionally, perform testing on the small scale version of components to determine optimal performance range.

# CONCLUSION

Hybrid and Electric vehicles definitely offer environmental benefits and will provide disposable income in the near future. Their ability to reduce carbon emissions made by transportation sector would be a tremendous help to the environment. The value of this technology is unmeasurable if it slow down the effects of Global Warming. The economic benefit to the U.S. household from the annual fuel savings will depend on the breakeven point of the hybrid investment. The price difference between the hybrid vehicle and the conventional vehicle has been trending downward due to the improvements to battery technology. Thus reducing the time needed to reach the breakeven point. In order to get the full economic benefit of hybrids, driving in all electric mode is required. If the commute range is 40 mile or less, the hybrid use only battery power. Electric vehicles they have a longer electric driving range than the hybrid vehicles.

So based on the National average commute being 40 miles or less the electric vehicle would be adequate for the nation's average commuter. Moreover, the respondents polling results yielded the average commute to be 32 miles. This is within the range of expectance based on national commute data.

One of the aims of this research was to determine likeability of the hybrid and electric vehicle. The majority of respondents rejected the purchase of an electric vehicle, in fear of running out of power while away from home. However the hybrid vehicle on the other hand, the majority polled accepted the idea of purchasing a hybrid vehicle. It should be noted that more respondents choose maybe buying a hybrid than those who chose not to.

REFERENCES

Baha Mohammed Al- Alawi, (2012). Techno-economic analysis and decision making for PHEV benefits to Society, consumers, policymakers and automakers.

Craig H. Stephan and John Sullivan, (2007). *Environmental and Energy Implications of Plug-In Hybrid Electric Vehicles. Environ. Sci. Technol.*, 2008, 42 (4), pp 1185–1190

Earth Talk: Are Hybrid Vehicles really better for the environment? (2009, Mar 12). El Chicano Weekly EPA climate change (2012) Retrieved from: http://www.epa.gov/climatechange/ghgemissions/gases/co2.html

Fontaras, Panayotis and Samaras (2008, June 18). Experimental evaluation of hybrid vehicle fuel economy and pollutant emissions over real-world simulation driving cycle. *Atmospheric Environment*, Volume 42, Issue 18, Pages 4023–4035

Jansen, Brown and Samuelsen (2010, Aug 15). Emission Impacts of Plug-In Hybrid Electric Vehicles Deployment on the U.S. Grid. *Journal of Power Sources* Volume 195, Issue 16, Pages 5409–5416.

W. Garth Sr. (2014, Jan 22). Cola-Cola transforms service vans to hybrid vehicles. Chicago Citizen.

# AN IMPROVEMENT TO THE STANDARD MICRO PILLAR DESIGN TO QUANTIFY CONTRACTION FORCES PRODUCED BY CARDIAC MYOCYTES

By Ahmedul Islam Major: Electrical Engineering Mentor: Dr. Ming-Cheng Cheng, Department of Electrical & Computer Engineering

#### ABSTRACT

A novel method is proposed to measure the contraction force produced by cardiac myocytes. This method is expected to have better sensitivity for measuring the contraction forces of cells compared to an existing technique such as micropillar array. The deflection of PDMS micro fabricated pillar array is associated with the magnitude and direction of the force the cells are applying. The divergence from the existing method is that the cardiac myocytes will not be placed directly on the pillars but instead atop a very thin PDMS layer that will be attached to the micropillars by covalent bonding. This method has gone through several tests and the results show that it is able to detect the cellular contraction force. The outcomes I hoped to achieve by using this method was to obtain more accurate. I have proven that my method works though many experiments and in the future I will compare this novel design with the standard design to see how the measurements relate.

*Keywords:* PDMS, cardiac/cardio myocytes, PDMS fabrication, micro pillars/posts micro mat, cellular/cell contraction force measurement

#### AN IMPROVEMENT TO THE STANDARD MICRO PILLAR DESIGN TO MEASURE CONTRACTION FORCES PRODUCED BY CARDIAC MYOCYTES

There are three major muscle cells in a human body: cardiac, smooth, and skeletal. In particular, the cardiac myocytes, also known as cardiac muscle cells, are closely related to the heart's functionality. The purpose of cardiac myocytes is to contract as the heart pumps blood and control the blood flow (Zhao and Zhang, 2006). Thus, understanding the contraction forces that cardiac myocytes generates is widely sought out because it correlates with the heart rate. Currently a standard way of measuring cell contraction force is using polydimethylsiloxane (PDMS) pillars but I will introduce a new method that builds on the standard method. This research was done to compare if this new proposed method is able to yield a better approach to detecting cell contraction force from the standard method (Zhao and Zhang, 2006).

The existing method uses PDMS pillars that deflect when cardiac myocytes that are placed on top of the pillars contract. PDMS is a clear, flexible material therefore it excels at being able to detect the force cells create as they contract. The standard method uses soft lithography, a micro-electric mechanical system (MEMS) process, to create the pillars (Sniadecki and Chen, 2007). This existing method is simple and easy to perform; therefore, this is a disadvantage that a more complex and natural design will overcome. There are multiple ways to making the micro PDMS pillars and after making my micro pillars I will modify the design by adding another thin layer.

This paper will expand upon the existing methods with the addition of another thin PDMS layer. Instead of the cardiac myocytes going directly on top of the pillars it will be placed on top of a thin PDMS layer. The thin PDMS layer will be cross-linked using plasma to the pillars and when the cells contract the thin layer will

deform also. This deformation will also cause the pillars to bend and by measuring the displacement of the bending we can find the contraction force those cells are creating (Zhao and Zhang, 2006). With the addition of the thin layer I hope to see an increase in sensitivity. The best outcome I expect to achieve is to have a novel method that provides more accurate measurements from the standard method.

# LITERATURE REVIEW

The article that was the foundation of this research was Sniadecki's and Chen's (2007) article that gave a very detailed explanation of how to measure contraction forces of cells using the standard method. This article explained how the cardiac myocytes work and why the contraction force is generated by the cells. The main focus of the paper was on how to micro fabricate PDMS pillars and how the pillars detect the contraction forces when they bend due to contraction forces (Sniadecki and Chen, 2007). He mentions how the micro pillars or posts act like vertical cantilevers and the cells, which are placed directly on top of the posts, contracts causing the posts to bend inward and that bending can be quantified (Sniadecki and Chen, 2007).

The method Sniadecki and Chen (2007) use to make the micro post is by soft lithography and using a photoresist material called SU-8. For my research I will use a different method that involves deep reactive ion etching (DRIE) to make holes on a silicon substrate that can be later used to make similar PDMS micro post. This way we will be able to produce and reuse more PDMS micro pillars with ease. The micro posts made by Sniadecki and Chen (2007) are similar to my design and functions the same way but differ in the sense that he makes pillars instead of holes on SU-8 photoresist by photolithography and does double mold casting to end up with PDMS pillars. Furthermore, Sniadecki and Chen (2007) give equations that can be used to find the theoretical value of the deflection in relation to sensitivity, diameter, and height of the post. These equations will be integrated in my research towards the end to compare if the forces I measure are close to what should be expected of cardiac cells to produce.

In the article by Legant et al. (2009) they use a similar technique to measure contraction forces of tissue instead of cells and on a 3D scale. My research aims to be able to measure contraction forces of cells however this article gives abundant information about the advantage of knowing these contraction forces. Chen also co-authored this article so it had many of the ideas that are similar to the paper by Sniadecki and Chen (2007) such as using PDMS as the material and measuring the contraction force of the tissue based on the deflection of the PDMS matrix. In addition, this article provides a lot of results that was obtained through measuring 3D tractional forces caused by tissue such as morphologic change, boundary mechanics change, and change in protein levels (Legant et al., 2009). All of these results were also supported by many simulations that were also provided in this paper that indicate that it is highly possible to measure tissue contraction force. If my research was to go into the next stage, measuring three-dimensional cellular contraction force would be the next area my research would include.

Designing the micro pillars is an important part of my research. The pillars have to be certain diameter, have a certain height, and be apart a certain length uniformly. The paper by Zhao and Zhang (2006) goes into a great depth at how varying the dimensions and shape of the pillars will affect the force measurement. There were numerous equations that were provided for the pillars and also what variables that I needed to use in the equations, such as the PDMS pillar's Young's modulus, moment of inertia, and height among others (Zhao and Zhang, 2006). Furthermore, actual tests were conducted by Zhao and Zhang (2006) and they noted how manipulating the dimensions of the pillar will result in different measurement of force and the spring constant on the pillar. This is all done by detecting the displacement of the tip of the pillar or cantilever that will result from the cell contraction.

Similar to the previous paper, the main focus of the article by Wang et al. (2002) was around measuring tractional forces. It included the standard method of using PDMS micro pillars to measure the contraction force of cells but the paper mostly focused on how the micro pillars will interact with the cells. They talked about the process of culturing cells to the PDMS pillars and how the cells needs to be patterned correctly to accurately measure tractional force. Additionally, they varied the cell size and shape to find that a smaller cell outputs less

traction force (Wang et al., 2002). Therefore, the size and shape of the cell is a factor I have to keep in mind for my research because this means the cells I will test must all be the same size. Another major finding in this paper was that they were able to clearly measure the traction force and displacement and it correspond closely with the size and geometry of what cell was lying on the pillar (Wang et al., 2002).

There are already many papers out there that have done research on traction force of cells. The difference between those papers and mine is that I will add an additional PDMS layer that will be attached to my PDMS pillars. The paper by Wu et al. (2005) talks a lot about bonding PDMS to PDMS. This article mentions that the bond between PDMS and PDMS is strong when exposed to radiation or plasma (Wu et al., 2005). For this research I bonded a thick PDMS pillar layer to a thin PDMS layer to remove the thin layer off of a substrate. This method worked because the cross-link between PDMS and PDMS is stronger than the bond between PDMS and glass if the PDMS is cured for longer (Wu et al., 2005).

I wanted my thin PDMS layer to have a thickness less than 1 micron. The paper by Thangawng et al. (2007) was able to achieve a thin PDMS layer thickness of 70 nm. The authors of this paper used a spin coater to make their thin PDMS, which is exactly what I have done in my research. The difference that was observed is that in the paper by Thangawng et al. (2007) he added hexane solution to help thin the PDMS. In my research I ramped up the revolution per minute on the spin coater and varied the time duration it spun the PDMS to get my thin PDMS layer. The paper showed that it is much more difficult to get a think pure PDMS layer than a diluted PDMS layer (Thangawng et al., 2007). With this information I will have to do many tests using the spin coater to obtain a thickness close to 1 micron.

#### METHODOLOGY

The initial phase of the project was to make a very thin PDMS layer and PDMS micro pillars separately. The PDMS I made was using Sylgard 184 base agent and curing agent at a 10:1 weight ratio (Sniadecki and Chen, 2007). The weight was measured by a Sartorius analytical balance model BP301S to obtain a 10:1 ratio. First, the base agent was poured into a container and then using a pipette, a tenth of the base weight of curing agent was added. Then, the two PDMS agents were thoroughly mixed using a small stick for five minute. When these two Sylgard 184 PDMS agents are mixed, the resulting PDMS have air bubbles inside them that I did not want because it affects the later procedures and the overall results. Therefore, I took my PDMS sample and put it in a Thomas vacuum pump model 900-58A until all the air bubbles in my PDMS samples were gone. At this point I have PDMS fluid that I can either use to make a thin mat layer or the micro pillars.

# Creating the Mat and Pillar

I made the thin PDMS layer on glass but before I could do that the glass had to be cleaned using a very strong acid called the piranha solution. The glasses were cut into squares of approximately 2.5 cm by 2.5 cm before put into the piranha solution. The piranha solution is made from a 3:1 ratio mixture of sulfuric acid and hydrogen peroxide and is intended to clean the glass at an organic level. All of the glass were dipped in the piranha for a few minutes and then dipped into two containers of deionized (DI) water. Afterwards, the glasses were dried using nitrogen gas and moved into the spin coater model WS-650MZ 23NPP/LITE. Once a piece of glass was saddled on the spin coater properly, the PDMS samples was poured at the center of the glass and then spun. The spin coater spun at 12,000 rpm, at an acceleration of 4000 rpm/s, for one minute duration. This yielded a thin PDMS of thickness close to 1  $\mu$ m. Right after the PDMS was spun, I put it in the VWR 1410 curing oven, which was also being vacuumed, for an hour at 114°C for the thin PDMS to cure. In the end, I had the final thin PDMS mat that I will use as the layer attached from above on my PDMS pillar after it cooled. Once it cooled I was also able to use a surface profiler to measure the thickness of the thin mat layer to be approximately 5.5  $\mu$ m.

Next, to make PDMS pillars I first needed a silicon wafer with holes. The dimensions I measured for my pillars were a height of 15  $\mu$ m, 38  $\mu$ m between each pillar, and a pillar diameter of 13  $\mu$ m. These holes that were made on the silicon substrate were made using deep reactive ion etching (DRIE) on the silicon substrate using a mask

that had the properties similar to my dimensions. DRIE is a micromachining technique used to make micro trenches with smooth walls for MEMS devices. The DRIE etching on the silicon substrate was done in the clean room at Wayne State University, like all MEMS fabrication is done, in a controlled environment. I obtained the silicon substrate with holes etched from Dr. Cheng. The next step was to attach a square metal piece of thickness 2 mm to the edges of the silicon substrate with tape. This way I was able to consistently make the base of the PDMS pillar a constant height. I then poured PDMS onto the wafer to get a leveled PDMS base and pillars that I put in the same curing oven. I use the same configuration of 114°C for 1 hour to cure the thick layer. Again, this is done in a vacuum to make sure there are no air bubbles and then cooled after being cured. Finally, I used a caliber to measure the dimension of the small cut-out of the thick PDMS pillar layer to be 2.5 cm by 2.5 cm by 2 mm.

# The Device and its Function

Having both the thin PDMS layer and the PDMS pillar I now went to the step to cross-link them with the intention to remove the thin layer from the glass. It is easy to remove the PDMS pillar that has a 2mm thickness so this method was made to remove the thin layer. I cut out a square from the PDMS pillar and placed it on the center of the clean glass. I used the BD-10AS high frequency generator from Electro-Technic Products, Inc., also called the corona, to enable cross-linking between the two PDMS layer. Instantly after using the corona, the two PDMS were attached together and the glass was put under pressure. After 15 minutes the glasses were pulled apart and the thick layer was now attached to the thin layer (Jo et al, 2000). Finally, using a small razor blade, a square of approximate size 1 cm by 1cm, was cut around the edges of the thick layer. By removing the thick layer again the thin layer was also removed from where the thick layer was attached. This was the process I used to make the PDMS micro device that will measure cell contraction force. When I compared this new design to the standard design all I had to do was leave out the thin PDMS layer.

Once the device is ready I send it to Dr. Lam's lab, whose lab provides and grows the cardiac myocytes, to handle the cell culturing on top of the thin PDMS layer that is cross-linked to the pillars. This process takes about a week and once it is complete she sends it back to me to measure the contraction force of cardiac myocytes. I use the Contour GT in Motion from Bruker to measure the deflection from the base of the PDMS pillars. This 3D optical microscope uses white light inferometry to measure the deflection of the pillars. By looking at the new position of the pillars, I can calculate the amount of force the cells applied to bend the pillars.

#### RESULTS

The main reason for this project was to see if the new device that we proposed can actually measure contraction force and it succeeded. I was able to distinguish the deflection of the pillars under the microscope but I have not yet measured the deflection. I am currently in the process of obtaining measurements from my devices. Afterwards, I will compare the new method I used to the standard method to observe how much more accurate my measurements are compared to the older method. This will be done by seeing how close each experimental measurement is to the theoretical measurement. This result can be used by Dr. Lam to understand the mechanical properties of cardiac myocytes and may be used to engineer cells that can create equal contraction force.

#### DISCUSSION

This device is not as simple as the standard methods but it is intended to yield more precise measurements of cellular contraction force. This new method is more preferable over the old because the increase in sensitivity; accuracy in measurement is a major part of experimentation and optimization. We have seen deflections of the pillars as the cells contracted however we need to look at many devices that were made using my new method to see if the data is consistent. Then we have to do the same process using the older method before we can make a comparison and obtain results. Within the next month I will have the measurements ready and the methods compared so the research can be closed and published.

#### REFERENCES

Jo, B.-H., Van Lerberghe, L. M., Motsegood, K. M., & Beebe, D. J. (2000). Three-dimensional micro-channel fabrication in polydimethylsiloxane (PDMS) elastomer. *Journal of Microelectromechanical Systems*, 9(1), 76-81. doi:http://dx.doi.org/10.1109/84.825780

Legant, W. R., Pathak, A., Yang, M. T., Deshpande, V. S., McMeeking, R. M., & Chen, C. S. (2009). Microfabricated tissue gauges to measure and manipulate forces from 3D microtissues. *PNAS*, *106*(25), 10097-10102. doi:http://dx.doi.org/10.1073/pnas.0900174106

Sniadecki, N. J., & Chen, C. S. (2007). Microfabricated silicone elastomeric post arrays for measuring traction forces of adherent cells. *Methods in Cell Biology*, *83*, 313-328. doi:http://dx.doi.org/10.1016/S0091-679X(07)83013-5

Thangawng, A. L., Ruoff, R. S., Swartz, M. A., & Glucksberg, M. R. (2007). An ultra-thin PDMS membrane as a bio/micro-nano interface: fabrication and characterization. *Biomed Microdevices*, *9*(4), 587-595. doi:http://dx.doi.org/10.1007/s10544-007-9070-6

Wang, N., Ostuni, E., Whitesides, G. M., & Ingber, D. E. (2002). Micropatterning tractional forces in living cells. *Cell Motility and the Cytoskeleton*, *52*(2), 97-106. doi:http://dx.doi.org/10.1002/cm.10037

Wu, H., Huang, B., & Zare, R. N. (2005). Construction of microfluidic chips using polydimethylsiloxane for adhesive bonding. *Lab on a Chip*, *5*, 1393-1398. doi:http://dx.doi.org/10.1039/b510494g

Zhao, Y., & Zhang, X. (2006). Cellular mechanics study in cardiac myocytes using PDMS pillars array. *Sensors and Actuators A*, *125*, 398-404. doi:http://dx.doi.org/10.1016/j.sna.2005.08.032

# ARDUINO: BANKING SYSTEM PROTOTYPE

By Kayla Jordan Major: Electrical Engineering Montor: Mr. Umar Khalid, PhD Car

Mentor: Mr. Umer Khalid, PhD Candidate, Department of Electrical & Computer Engineering



#### INTRODUCTION

Curious minds that want to design and implement their own circuits all have to start from somewhere. Arduino is known as the "hobbyist" kit to a lot of the circuitry world. Arduino is a very useful hardware. It is largely used for hobbyists who want ease of implementation but still enough processing power to handle a multitude of tasks programmed by the user. There have been a variety of projects created using Arduino, such as clocks, simulated traffic intersections and counting systems.

#### ARDUINO SPECIFICATIONS

Arduino boards are comprised of usually a single-board microcontroller (8-bit or 32-bit), 6 analog pins and 14 input/output pins. Arduino has been in wide use since 2005. The boards are pretty inexpensive, and can cost up to \$30. Arduino is pretty versatile, with a lot of combinations that can be used with the digital and analog signals.

Arduino operates at the highest voltage of 5 volts. It communicates to the Arduino software using an USB port. To those who have some programming skills, the software has some Java and C++ similarities. (Arduino.cc)

# HYPOTHESIS: STUDY

Usually with circuit design, there is a problem that the engineer/company is trying to solve for the customer. Depending on the needs of the customer, the engineer can create a smaller version of the final product. The circuit engineer can build a small prototype on a solderless (bread) board, and run some tests/diagnostics before moving to a bigger scale. This allows for the engineer to add/remove some features and demonstrate the abilities of the soon-to-be-produced equipment.

#### PROBLEM

A bank is currently experiencing issues with their security system. They would like to have an automated system that can inform customers that they are open, allow customers to use an interface to tell the ATM if they would like to deposit or receive money, and finally keep the bank safe with an alarm system. A model prototype has to be designed before they will proceed with installing the new system. Arduino, being very easy to use and able to accommodate all the needs of the bank, will be utilized.

#### PROPOSED SOLUTION

This project will use a variety of digital and analog components, such as LEDs, proximity sensors, button sensors and sound sensors. The Duemilanove board will be used, as it has digital and analog capabilities. The project will be designed in the form of a bank, using common household items such as a cardboard box and decorations. Each of the sensors and their functions will be detailed below:

A green digital LED will be used for 3 functions: to signal that the bank is "open", to signal to the "patron" that they can enter into the bank, and to alert the teller that a patron has walked into the building. A red digital LED will be used for 2 functions: to signal that the bank is "closed", and show that the alarm system has been set.

An analog photoresistor will be used for 1 function: to alert the Arduino board of the "time of day" of the bank. An analog proximity sensor will be used for 1 function: to signal that a "patron" is close to the entrance. A sound alarm will be used for 1 function: to sound if the "alarm" is triggered. A digital button sensor will be used for 2 functions: to stop the "alarm" and signal the "all clear", and to inform the teller what the "patron" wants to do while at the bank.

Carbon film resistors with resistances of 330 Ohms to 10KOhms will be used to ensure that the current does not burn out any of the equipment. A Servo motor will also be used to open/close the bank door. All code will be written using Arduino software. The Fritzing website will be used to display the schematics of the circuit along with a model of the components in use.

#### RESULTS

The results for the prototype were well. The only sensors that were not used from the proposed solution were the analog proximity sensor and the Servo motor. A sensor added was an analog pressure sensor for resetting the alarm, which will be explained later in the code section of the results. The circuit performed to expectations, and all the times that it was run after completion, there were no serious issues.

# CODE

By using a series of "if-else if" loops nested within the looping void of the Arduino board, the circuit was able to be continuously run without having to restart the microcomputer. Previously defined conditions had to be met for the circuit to perform certain tasks. For instance, the photoresistor had to receive analog signal values between 300 and 600 for the circuit to be in "daytime" mode. Otherwise, the circuit would be in "alarm mode" because of the smaller "night time" analog values received.

```
int green = 7; //green LED for alerting patron that bank is open
int red = 5;
int white = 3;
int buttonpin = 8;
int alarm = 10;
int lightpin = 2;
int pressurepin = 0;
int bankhours = 0;
int note = 1000;
int val;
int val;
int val;
int pressure;
int pressure;
int ATM = 0;
int ATMmode;
```

Figure 1: Initialization of variables

In the above piece of code, all the sensors, pins and condition variables are initialized. "Green", "red", and "white" are the pins for the respective colored LEDs. "Buttonpin" is the pin number for the digital button sensor. "Alarm" is the pin number for the digital pievo sensor. "Lightpin" is the pin number for the photoresistor. "Pressurepin" is the pin number for the analog pressure sensor. "Bankhours", "note", "ATM" and "ATMmode" are initial values that aid later in the condition coding. "Val" and "val2" are for the initial values for the code involving comparing signals received from the digital button.

```
void setup() {
   pinMode(buttonpin, INPUT);
   pinMode(green, OUTPUT);
   pinMode(red, OUTPUT);
   pinMode(alarm, OUTPUT);
   Serial.begin(9600);
   ATMmode = digitalRead(buttonpin);
}
```

Figure 2: Setup for pins on Arduino board

In this piece of code, I used a setup void. "pinMode" is used to tell the Arduino board what pins should be inputting or outputting signals. "Buttonpin", inputting signals from the digital button to the board, is set to "INPUT". "Green", "Red" and "Alarm" are all going to output signals from the board. The "Serial.begin(9600)" piece tells the Arduino board to process at 9600 bits/second. "ATMmode" needs to have values digitally read from the "Buttonpin" pin number.

```
void loop() {
  bankhours = analogRead(lightpin);
  Serial.println(bankhours);
  if (bankhours > 300 && bankhours <600) {
    noTone(alarm);
  val = digitalRead(buttonpin);
  delay(10);
  val2 = digitalRead(buttonpin);
  if (val == val2) {
    if (val != ATMmode) {
      if (val == LOW) {
        if (ATM == 0) { //if Green light is off
          ATM = 1; //Patron wants money. Green should blink.
        }
        else{
          if (ATM == 1) { //if Green light is on
            ATM = 2; //Patron wants to deposit money. White should blink
          3
          else{
            if (ATM == 2) { //if White is blinking,
              ATM = 3; //Patron wants to deposit money. Red should blink
            }
           else{
            if (ATM == 3) { //if Red is blinking,
              ATM = 4; //Patron is done. Loop back to beginning.
            3
            else{
              if (ATM == 4) {
                ATM = 0;
```

Figure 3: Looping of "Day Time" Banking System

In this loop void, there is a combination of "if-else if" statements. "Bankhours" needs to read analog values from the "lightpin" pin first. This will help the Arduino processor determine if it is in "daytime" mode or "night time" mode. If the analog "lightpin" sensor is reading values between 300 and 600, the Arduino processor is going to enter "daytime" mode. Because the alarm should not be set, a "noTone(alarm)" had to be used so that the alarm would not be activated. "Val" and "val2" are digitally read to verify that the "buttonpin" has received a digital signal from the button sensor. If "Val" and "val2" both have a value of 1 (meaning "button has been pushed"), then the "ATMmode" value will change. With each button push, the "ATMmode" will increase by 1. With the fourth push, the "ATMmode" will reset to 0, restarting the entire banking system.

```
÷
 ATMmode = val;
if (ATM == 0) {
digitalWrite(green, LOW);
digitalWrite(red, LOW);
  }
if (ATM == 1) { //Patron just wants money!
digitalWrite(green, HIGH);
delay(1000);
digitalWrite(green, LOW);
delay(1000);
}
if (ATM == 2){ //Patron wants to make deposit!
digitalWrite(white, HIGH);
delay(500);
digitalWrite(white, LOW);
delay(500);
}
if (ATM == 3) {
  digitalWrite(green, LOW);
  digitalWrite(red, HIGH);
  delay(500);
  digitalWrite(red, LOW);
  delay(500);
}
}
```

Figure 4: Possible ATM modalities for each digital button press

In this piece of code, the "ATMmode" value is now set to the "val" variable. When LEDs are being digitally written "LOW", this means that the LEDs are off. When they are being digitally written "HIGH", this means that the LEDs are on. If "ATMmode" is equal to 0, the LEDs should both have low values.

- 1. If "ATMmode" is equal to 1, the green LED should be written HIGH for one second, and then written LOW for 1 second. This will cause the LED to blink. When "ATMmode" is 1, this means that the bank is open.
- 2. If "ATMmode" is equal to 2, then the white LED should be written HIGH for half a second, and then LOW for half a second. When "ATMmode" is 2, this means that the patron wants to withdrawal money.
- 3. If "ATMmode" is equal to 3, then the red LED should be written HIGH for half a second, and then LOW for half a second. When "ATMmode" is 3, this means that the patron this means that the patron wants to make to deposit money.
- 4. If "ATMmode" is equal to 4, then the banking system will reset and go back to "ATMmode" being equal to 0. This means that the system is ready for the next patron.

```
}
}
else if (bankhours > 0 && bankhours < 150){
 ATMmode = digitalRead(buttonpin);
 pressure = analogRead(pressurepin);
 Serial.println(pressure);
  digitalWrite(green, LOW);
  digitalWrite(red, HIGH);
  delay(200);
  digitalWrite(red, LOW);
  delay(200);
  if (ATMmode == 1) {
    tone(alarm, 2349);
    digitalWrite(red, HIGH);
    delay(4000);
  -}
  if (pressure > 200 && pressure <= 400) {
    noTone(alarm);
    ATMmode = 0;
  3
}
3
```

Figure 5: Looping of "Night Time" Banking System/Alarm System

In the above code, the condition code has been set for the "night time" hours of the bank. The photoresistor has to be between the analog values of 0 and 150. The button sensor and pressure sensor have to be read for digital and analog values. Only the red LED should be on and blinking because the bank system is now in "alarm mode". If the "buttonpin" inputs a voltage signal during the alarm mode, then the piezo speaker will sound and the red LED will not blink. The pressure sensor needs to be used to stop the alarm buzzer. The pressure sensor needs to output values between 200 and 400. Once that condition is met, the alarm buzzer will stop. The red LED will go back to blinking, waiting for the next "intruder" to attempt to break into the banking system.

BREADBOARD AND SCHEMATICS



Figure 6: Fritzing Breadboard Display of Banking System Circuit



Figure 7: Fritzing Schematic Display of Banking System Circuit

Fritzing (fritzing.org) is a free software that allows circuit designers to create breadboard diagrams and schematic displays. By simple dragging and clicking, a circuit can be recreated. At the same time, the Fritzing software will create the schematic for the board.

# CONCLUSION

This project taught me a lot about coding and wiring circuits. I have never designed my own circuit before, so it was very fun and interesting to do. It helped me think like an engineer, and how I could satisfy the "customer" the best way I could.

#### REFERENCES

Arduino Microcontroller Photo: www. liquidware.com

All code photos were created by Kayla Jordan using the Arduino 1.0 coding software, on August 18, 2014.

All Fritzing displays were created in the Fritzing software, on August 14, 2014.

# RELATIONSHIP BETWEEN PSYCHOLOGICAL DISTRESS AND INFLAMMATION IN PREGNANT AFRICAN AMERICAN WOMEN

# By Maricruz Moya

Major: PreNursing Mentor: Dr. Carmen Giurgescu, College of Nursing

# ABSTRACT

Preterm birth (less than 37 weeks gestation) is still an issue in well developed nations. African American women have a higher chance of preterm birth compared with non-Hispanic white women. Experiencing high levels of psychological distress has been related to higher levels of inflammation. Both psychological distress and inflammation have been related to preterm birth. The purpose of this study was to examine the relationships among psychological distress, inflammation and gestational age at birth in a sample of 114 low-risk pregnant African American women. Women completed questionnaires and had blood draw during their pregnancy. Higher levels of psychological distress were related to higher levels of pro-inflammatory cytokines of IL-6 and IL-8. Gestational age at birth was not related to psychological distress or inflammation. These results are useful for understanding the impact of psychological distress on inflammation. Clinicians need to develop interventions that have the potential to decrease psychological distress for pregnant women with potential to improve pregnancy outcomes.

African American women carry the largest burden of poorer pregnancy outcomes. Martin and colleagues (Martin et al., 2010) reported that African American women are 1.6 times more likely to experience preterm birth compared with non-Hispanic white women. Psychological stress has been related to preterm birth (Martin et al., 2010). Stress can be defined as events, situations, emotions and interactions that negatively affect the wellbeing of the individual (Coussons-Read et al., 2012). Psychosocial stress may increase inflammatory markers and alter cytokine production across pregnancy. These pro-inflammatory markers are involved in the ripening of the cervix and stimulation of the uterine contraction in preparation for labor and birth(Challis) et al., 2009; (Golightly), Jabbour, & Norman, 2011).

The human body is an interesting organism. In its attempt to constantly maintain homeostasis, it uses techniques such as inflammation to combat imbalances. The hypothalamic-pituitary-adrenal (HPA) is responsible for this function. A normal pregnancy requires a balance is the aspect of the immune, endocrine and nervous system that delicately shifts through the course of pregnancy to support maternal and fetal wellbeing. The perturbation of this balance increases the risk of "poor pregnancy "outcomes (Maina et al., 2008). Factors such as psychological distress can lead to negative outcomes, such as preterm birth.

African American women report higher levels of stress and depressive symptoms during pregnancy than Caucasian women (Canady, Bullen, Holzman, Broman, & Tian, 2008). Studies have shown that stress is related to an increase in cytokine levels in particular pro-inflammatory cytokine Interleukin-6 (IL-6) (Coussons-Read, Okun, & Nettles, 2007). High levels of stress may result in release of IL-6 which can stimulate contractions that lead to preterm birth (Coussons-Read, Okun, Schmitt, & Giese, 2005) For this study, the hypothesis was that psychological stress leads to alterations in the HPA axis, thereby deregulating inflammation and predisposing African American women to preterm birth. Therefore, the purpose of this pilot study was to examine the relationships among psychological distress, inflammation, and gestational age at birth in a sample of African American women. Specifically, this study examined the: (1) relationships among psychological distress,

inflammation and gestational age at birth; (2) differences in inflammation and gestational age at birth between women with psychological distress and women without psychological distress.

# LITERATURE REVIEW

Research suggests that psychological distress is related to inflammation in pregnant women. Coussons-Read and colleagues (Coussons-Read et al., 2012) examined the relationships among overall stress, pregnancy specific distress and pro-inflammatory cytokine IL-6 in a sample of 173 pregnant women. Data were collected two times during pregnancy [early (14-18 weeks) and late (28-32 weeks) in pregnancy] and one time after birth. They found that women with preterm birth had higher levels of IL-6 in early, late and averaged across pregnancy specific distress late and averaged across pregnancy compared with women with term birth. Furthermore, women with preterm birth had higher levels of pregnancy specific distress late and averaged across pregnancy distress and IL-6 in early, late or averaged across pregnancy. Women who had higher levels of pregnancy distress and IL-6 early, late and across pregnancy were more likely to have lower gestational age at birth. This findings suggests that psychological distress is related to IL-6 and gestational age at birth.

In another study, Coussons-Read and associates (Coussons-Read et al., 2007) examined the relationship between stress and inflammation three times during pregnancy [first (14-16), second (22-24, and third (34-36 weeks) trimester] in a sample of 52 pregnant women. They found that stress predicts IL-6 levels in the first and third trimester of pregnancy. Compared with women who had low stress levels, women who had high stress levels had higher levels of IL-1 $\beta$  and IL-6. These results further support prior findings that stress is related to inflammation.

Other studies have examined the relationship between depressive symptoms, a component of psychological distress, and inflammation. For example, Cassidy-Bushrow and associates (Cassidy-Bushrow, Peters, Johnson, & Templin, 2012) examined the relationships between depressive symptoms and inflammatory markers (IL-6, IL-1 $\beta$ ) in a sample of 187 pregnant women between 13-28 weeks. Higher levels of IL-1 $\beta$  were related to higher levels of IL-6. Women who had higher levels of depressive symptoms also had higher levels of IL-6 and IL-1 $\beta$ . There were no difference in depressive symptoms and inflammatory markers between women with preterm birth and women with term birth. These results suggest that depressive symptoms are related to inflammation, but there are no differences in depressive symptoms or inflammation between women with preterm birth and women with term birth.

Similarly, Christian and colleagues (Christian, Franco, Glaser, & Iams, 2009) examined the relationships among perceived stress, depressive symptoms and IL-6 at an average of 15 weeks in a sample of 60 pregnant women. They found that higher levels of depressive symptoms predicted higher levels of IL-6. Perceived stress was not related to IL-6. These findings suggest that depressive symptoms are related inflammation. Therefore, this literature review shows that psychological distress is related to higher levels of inflammation and lower gestational age at birth; however, findings are inconclusive. Therefore, we proposed to examine the relationships among psychological distress, inflammation, and gestational age at birth.

# METHODS

# Design

This pilot study used a longitudinal descriptive exploratory design. Data were collected twice during pregnancy (16-22 weeks and 26-32 weeks) and once after birth.

# Sample

For this pilot study, a sample of 114 pregnant African American women were recruited from a medical center in Chicago. Women were enrolled into the study if they were at least 18 years of age; had singleton pregnancy; and had a low risk pregnancy. Women with medical diagnosis (e.g., chronic hypertension, diabetes), obstetrical complications (e.g., incompetent cervix), or receiving steroid treatment were excluded since these factors may

influence the biological markers, may pose as stressors, and may increase the risk for preterm birth. At the first data collection, six questionnaires were not completed or were lost in the mail. Nine samples were either not collected or not processed within three hours of venipuncture and were not included in the analysis. One woman declined participation after completing the blood draw for first data collection. We excluded one participant who had significantly elevated levels of cytokines compared with the other participants. This participant was in the hospital within the prior 24 hours of blood draw because her child was sick and it is possible that acute stress in combination with lack of sleep to have affected the results. A sample of 102 women had both questionnaires and blood draw at the first data collection. At the second data collection, four women failed prenatal visits between 26-32 weeks, three women changed providers, two women had termination of pregnancy, two women declined participation for the second data collection. In this study we report the results for the 90 women who completed second data collection.

#### VARIABLES AND INSTRUMENTS

# Maternal Characteristics

Maternal characteristics including socio-demographic and obstetrical characteristics (e.g., maternal level of education, employment, income, prior pregnancies) were collected from self-administered questionnaires and medical records.

# Psychological Distress

The Psychological General Well-Being Index contains 22 items on a 6-point Likert scale and has six subscales: positive well-being, general health, vitality, depressed mood, anxiety, and self-control (Dupuy,1984). Scores range from 0 to 110, with some items being reverse-coded. Scores below 72 represent psychological distress (see Appendix I).

#### Inflammation

Serum cytokine analysis (IL-1β, IL-6, and IL-8) were measured by multiplex bead immunoassays.

*Gestational age at birth* was collected from medical records and it was calculated based on the last monthly period (LMP) and confirmed by ultrasound examination in the  $1^{st}$  or  $2^{nd}$  trimester.

#### PROCEDURE

Women receiving prenatal care at midwifery practice and who fit the inclusion criteria into the study were invited to participate. Women completed the questionnaires by themselves in a private room before or after their prenatal visit or took them at home and mailed them at a later date. The participant's venous blood was drawn through antecubital venipuncture (within 30 sec. of venipuncture) by the principal investigator or research assistants who have experience in collecting blood by venipuncture as Labor and Delivery nurses. Participants received a monetary incentive of \$25 each data collection point for their participation and time (total \$50). The blood samples were transported on ice to the laboratory where they were centrifuged and aliquoted within 3 hours of withdrawal. The aliquoted samples were frozen at -80°C until cytokines were assayed by the laboratory technician according to the manufacturer's specification. Gestational age at birth was obtained by the research assistants from the medical records. Four women were contacted within three months of birth because they did not deliver at the hospital affiliated with the midwifery practice.

#### DATA ANALYSIS

Data were entered, cleaned and prepared for analysis on an ongoing basis by the principal investigator or research assistants using SPSS 20. Blood samples that were below the limits of detection in duplicate wells were

replaced with the value of 0. This occurred without sampling errors indicating that the values were valid but below detection threshold (Luminex, Riverside CA). Log transformation was conducted for pro-inflammatory cytokines. Pearson r correlation coefficient was conducted to examine relationships among psychological distress, inflammation and gestational age at birth. In order to examine the differences in inflammation between women with psychological distress and women without psychological distress, we conducted independent sample t-tests.

# RESULTS

# Maternal Characteristics

Women had a mean age of 24 years of age. They had a mean gestational age at time of second data collection of 29 weeks and a mean of gestational age at birth of 39 weeks. Nine women had preterm birth. Majority of women were single (83.3%), with some college education (39.8%), unemployed (51.9%), and had an household income of less than \$10,000 (50%) (see Table 1).

# Table 1. Maternal characteristics

Variable	Mean	Range
	(Standard Deviation)	
Age	23.38 (5.29)	18-41
Gestational Age at data collection	29.09 (2.68)	20-37.5
Gestational Age at birth	39 (2.65)	23-41
Birth weight (grams)	3140 (717)	400-4556
	Number (%)	
Preterm birth	9 (8.4)	
Marital Status		
Single	90 (83.3)	
Married	18 (16.7)	
Education	15 (13.9)	
Less than HS	28 (25.9)	
Graduated HS	43 (30.8)	
Some College	+3 (37.0)	
Associate Degree	8 (7.4)	

Bachelor Degree	11 (10.2)	
Graduated Program or higher	3 (2.8)	
Employment		
NO	56 (51.9)	
YES	52 (48.1)	
Income		
Less than 10,000	51 (50.0)	
11,000-20,000	13 (12.7)	
21,000-30,000	22 (21.6)	
More than 31,000	16 (15.7)	

Relationships among psychological distress, inflammation and gestational age at birth

Psychological distress was positively related to IL-6 (r=.175, p<.05) and IL-8 (r=.227, p<.05). Levels of proinflammatory cytokines were positively related to each other. Gestational age at birth was not related to psychological distress or pro-inflammatory cytokines of IL-1 $\beta$ , IL-6 or IL-8 (see Table 2).

 Table 2. Relationships among variables (N=90)

Variable	Gestational	Psychologica	IL-1β	IL-6
	age at birth	1 distress		
Gestational age at birth	—			
Psychological distress	.097	—		
IL-1β	.085	.165		
IL-6	.149	.175*	.768**	
IL-8	.011	.227*	.620**	.717**

\*p<.05 one-tailed; \*\*p<.001 one-tailed

Differences in inflammation and gestational age at birth between women with psychological distress and women without psychological distress

There were no differences in pro-inflammatory cytokines or gestational age at birth between women with psychological distress and women without psychological distress (see Table 3).

Table 3. Differences in cytokines and gestational age at birth between women with psychological distress and

women without psychological distress (N=90)

	No Psychological	Psychological	t-Test
	Distress (N=64)	Distress	
	(MEAN)	(N=26)	
		(MEAN)	
IL-1β	.50	1.24	979
IL-6	-1.66	34	-1.146
IL-8	16	1.07	-1.655
Gestational Age at	39.23	38.99	.683
Birth			

# DISCUSSION

In this study we found that psychological distress was related to inflammation in a sample of pregnant African American women. However, there was no relationship between gestational age at birth and psychological distress or inflammation. , Coussons-Read (2012), Coussons-Read (2012), also found that psychological distress and/ or depressive symptoms are related to higher levels of inflammation. The results are inconclusive regarding the relationship between gestational age at birth and psychological distress or inflammation. For example, Coussons-Read found that women who had more psychological distress and inflammation also had lower gestational age at birth (Coussons-Read et al., 2012). However, C did not find any differences in depressive symptoms or inflammation between women with preterm birth and women with term birth (Cassidy-Bushrow et al., 2012). These results suggest the need for additional studies with larger sample size to examine the impact of stress and inflammation on gestational age at birth.

# LIMITATIONS

There were few limitations for this research study. For example the sample size was small and the results can not be generalized to other populations. Future studies need larger sample size to detect statistical significant difference in inflammation and gestational age at birth between women with psychological distress and women without psychological distress. Only African American women were included in the study. Therefore the result can not be generalized to other racial population such as White, or Hispanic. Women had medically low risk pregnancy. Therefore the results cannot be generalized to high risk pregnant women. Women had low social economic status and fewer financial resources. Therefore, women may have higher levels of stress and worries of not being able to provide for the newborn. Finally, 12 women did not complete data collection and it is not known if they had different levels of psychological distress and inflammation compared with women who completed data collection.

#### Clinical Implications

Women who had higher psychological distress also had higher levels of inflammation. Health care providers need to assess the levels of psychological distress of pregnant women and recommend strategies for them to cope with their psychological distress. Referrals to mental health providers should be made for women who report severe psychological distress. Behavioral changes such as physical activity have been shown to decrease the levels of stress in pregnant women. In a systematic review, (Shivakumarm S et al., 2011) found that pregnant women who maintained an active lifestyle reported lower levels of depression compared with pregnant women who had a sedentary lifestyle. Therefore, health care providers may recommend pregnant women to maintain an active lifestyle during pregnancy which may be beneficial in decreasing psychological distress. Social support from partner, family or friends has been shown to decrease psychological distress in pregnant (Giurgescu, Penckofer, Maurer, & Bryant, 2006). Health care providers should encourage the support person to come to prenatal visits and participate in care. Home visits conducted by registered nurses for women who report psychological distress may also provide additional support for these women and decrease their levels of stress.

#### Recommendations for research

Future studies need to examine the relationships among psychological distress, inflammation and gestational age at birth with large sample size in multiethnic population. Longitudinal studies are recommended to examine these relationships across pregnancy for a better understanding of the impact of psychological distress on birth outcomes. Furthermore, studies on the differences in psychological distress between urban and rural pregnant women need to be considered.

#### CONCLUSION

This study found that pregnant African American women who had higher levels of psychological distress also had higher levels of inflammation. Therefore, psychological distress may result in physiological changes that have been implicated in preterm birth. Interventions need to be developed to decrease psychological distress of pregnant women with the potential to reduce the rates of preterm birth and improve the health of women and their infants.

#### REFERENCES

- Canady, R. B., Bullen, B. L., Holzman, C., Broman, C., & Tian, Y. (2008). Discrimination and Symptoms of Depression in Pregnancy Among African American and White Women. *Women's Health Issues*, 18(4), 292-300.
- Cassidy-Bushrow, A. E., Peters, R. M., Johnson, D. A., & Templin, T. N. (2012). Association of depressive symptoms with inflammatory biomarkers among pregnant African-American women. *Journal of Reproductive Immunology*, 94(2), 202-209.
- Challis, J. R., Lockwood, C. J., Myatt, L., Norman, J. E., Strauss, J. F., 3rd, & Petraglia, F. (2009). Inflammation and pregnancy. Reprod Sci, 16(2), 206-215.
- Christian, L. M., Franco, A., Glaser, R., & Iams, J. D. (2009). Depressive symptoms are associated with elevated serum proinflammatory cytokines among pregnant women. *Brain, Behavior, and Immunity,* 23(6), 750-754.

- Coussons-Read, M. E., Lobel, M., Carey, J. C., Kreither, M. O., D'Anna, K., Argys, L., . . . Cole, S. (2012). The occurrence of preterm delivery is linked to pregnancy-specific distress and elevated inflammatory markers across gestation. *Brain, Behavior, and Immunity*, 26(4), 650-659.
- Coussons-Read, M. E., Okun, M. L., & Nettles, C. D. (2007). Psychosocial stress increases inflammatory markers and alters cytokine production across pregnancy. *Brain, Behavior, and Immunity*, 21(3), 343-350.
- Coussons-Read, M. E., Okun, M. L., Schmitt, M. P., & Giese, S. (2005). Prenatal stress alters cytokine levels in a manner that may endanger human pregnancy. *Psychosomatic Medicine*, 67(4), 625-631.
- Giurgescu, C., Penckofer, S., Maurer, M. C., & Bryant, F. B. (2006). Impact of uncertainty, social support, and prenatal coping on the psychological well-being of high-risk pregnant women. *Nursing Research*, 55(5), 356-365.
- Golightly, E., Jabbour, H. N., & Norman, J. E. (2011). Endocrine immune interactions in human parturition. Mol Cell Endocrinol, 335(1), 52-59. doi: 10.1016/j.mce.2010.08.005.
- Maina, G., Saracco, P., Giolito, M. R., Danelon, D., Bogetto, F., & Todros, T. (2008). Impact of maternal psychological distress on fetal weight, prematurity and intrauterine growth retardation. *Journal of Affective Disorders*, 111(2-3), 214-220.
- Martin, J. A., Hamilton, B. E., Sutton, P. D., Ventura, S. J., Mathews, T. J., & Osterman, M. J. (2010). Births: final data for 2008. *National vital statistics reports : from the Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System*, 59(1), 1, 3-71.
- Shivakumarm S, G., Brandonm S, A. R., Snell, P. G., Santiago-Munoz, P., Johnson, N. L., Trivedi, M. H., & Freeman, M. P. (2011). Antenatal depression: a rationale for studying exercise. *Depression and Anxiety*, 28(3), 234-242. doi: <u>http://dx.doi.org/10.1002/da.20777</u>



The following questions ask how you feel and how things have been going with you during the past month, including today. For each question, please check the answer which best applies to you by checking the box.

- 1. How have you been feeling in general?
  - In excellent spirits
  - In very good spirits
  - In good spirits mostly
  - I have been up and down in spirits a lot
  - In low spirits mostly
  - In very low spirits
- 2. How often were you bothered by any illness, bodily disorder, aches or pains?
  - Every day
  - Almost every day
  - About half of the time
  - Now and then, bur less than half the time
  - Rarely
  - None of the time
- 3. Did you feel depressed?
  - Yes to the point that I felt like I wanted to die
  - Yes to the point that I did not care about anything
  - Yes very depressed almost every day
  - Yes quite depressed several times
  - Yes a little depressed now and then
  - No never felt depressed at all
- 4. Have you been in firm control of your behavior, thoughts, emotions, and feelings?
  Yes, definitely so
  - □ Yes, for most part
  - Generally so
  - Generally so
  - Not too well
  - No, and I am somewhat disturbed
  - No, and I am very disturbed
- 5. Have you been bothered by nervousness or your "nerves"?
  - Extremely so to the point where I could not work or take care of things
  - Very much so
  - Quite a bit
  - Some enough to bother me
  - A little
  - Not at all

Please turn to the next page.

17

# VEHICLE-TO-VEHICLE COMMUNICATIONS A SOFTWARE APPROACH TO DEVELOP CLUSTER BASED DSRC SAFETY MESSAGES

By Jason Shepherd Major: Computer Technology Mentor: Dr. Ece Yaprak, Engineering Technology Division, College of Engineering

#### ABSTRACT

What would you say if you were told that software is the key to solving the link breakage concerning V2V communications? This software solution would alert drivers to an oncoming collision, a collision that may be due to an obstruction of one's view or sudden stops, and allows the driver ample response time to avoid the collision. With this technology, lives can be saved; traffic congestion cleared, and costs from damage avoided. With the many different technologies being researched concerning V2V, it was decided to use a software-defined approach to solve the problem concerning the break in links between nodes caused by the rapidly changing mobility needs of V2V networks. What this means is no link, no communication between vehicles. In this paper we attempt to simulate a V2V communications protocol design by using the following technologies: OMNeT++ IDE, SUMO, and VEINS. This paper delves into various protocols and technologies used for VANETS, both past and present. To deal with these rapidly changing networks, a splay tree data structure implementation is used in conjunction with DSRC technologies for this design.

Vehicle-to-Vehicle Communications (V2V) is a vital approach to the technological advancement of vehicular safety. Developing a communication systems protocol, "a system of digital rules for message exchange within or between computers" is an important step in the process to create a set of standards within the V2V topology. V2V is currently a hot topic in the auto and computer engineering industries, and the race to develop the best protocol dates back to as early as 2004. The Federal Communications Commission (FCC) has allocated a spectrum of 5.9 GHz, of which 75 MHz are assigned for Dedicated Short Range Communications (DSRC) use. One of the major areas of research in vehicle ad hoc networks is the transmission of safety messages with the shortest delay in latency to prevent possible collisions.

Different protocols and designs are being used for the development of these networks. While many of these protocols function efficiently, a majority tends to rely on roadside units to aid in the broadcasting of safety messages. A more independent and less-costly solution for these communications needs to be developed, especially for less-populated and rural areas. In this review, we look into the research that some industry professionals have and are currently conducting on the scope of V2V communications. Also discussed is the relevancy of their work to this experiment, by combining elements of their work to use as a basis for this experiment. An attempt to design a new protocol by implementing it using the OMNeT++ IDE and then proceeded to test it using traffic simulation software. Exploring the following author's work on this subject inspired this works research questions.

#### LITERATURE REVIEW

# Safety messaging in DSRC

In 2004, Xu, Mak, & Sengupta (2004) designed various protocols using both synchronous and asynchronous logic under the 802.11a radio bandwidth, to determine whether rapid repetition of broadcast messages are efficient or not. Besides determining a packet's useful lifespan, the authors were able to develop an ad-hoc like

network without the use of RSU's. The authors defined two distinct qualities of service, named "Probability of Reception Failure"(PRF) and "Channel Busy Time"(CBT) respectively. CBT evaluates the channels efficiency rate, which takes the total length of time periods within T time period. T stands for the time the channel is occupied with safety messages. PRF is dependent upon both the messages range and definition of message lifetime.

The authors developed a protocol without the need of roadside units (RSU). This design allowed for the sending and receiving of messages without the need for receiver feedback, using DSRC, therefore not using (ready to send/ clear to send (RTS/CTS) states. They were able to accomplish this task by developing a mac extension layer state machine using synchronous and asynchronous logic with each having three different protocols. This particular extension state machine lies between the Media Access Control (MAC) and Logical Link layers. The tests were run using Network Simulator-2 and SHIFT, a traffic simulator. These authors work differs from the other studies in that they did not rely on roadside units, instead they used 802.11a radio spectrum at 5.4 GHz rather than 5.9 GHz that is allotted for 802.11p message delivery between vehicles.

This article is relevant to this research by demonstrating the possibility of developing a vehicular area network (VANET) using DSRC with no need for RSU's. It also defines a packets useful lifespan. This research will differ from theirs in that OMNeT++, VEINS, and SUMO will be used for the simulation of the created protocol.

# Urban Multi-Hop Broadcast Protocol

Korkmaz, Ekci, Ozguner, and Ozguner (2004) proposes a new protocol to combat the hidden node problem based off of the 802.11 standard using two specific methods which they refer to as directional broadcast and repeater broadcast. The latter uses roadside units at intersections. This protocol is concerned with inter-vehicle communications using carrier sense multiple access with collision avoidance (CSMA/CA). These researchers developed their own wireless simulator and then emulated vehicle road behavior using MATLAB software.

The basis of their study assumes that each vehicle is equipped with Global Positioning System (GPS) to find their location. The authors define their algorithm to work as follows: the node that is farthest from all other nodes is elected as the broadcasting node and is given an ID. Once a node receives its ID, an ACK is sent out. However, since this is a one-directional broadcasting scheme, the lead node sends the acknowledgement (ACK) to the RSU, and only to the RSU. This in turn lets the node know if the channel is empty and ready to receive. Once the first RSU is notified, it then notifies other RSUs within range for network safety and configuration.

This article was an inspiration to come up with an alternative solution to GPS. The main reason is that it cannot be assumed that all vehicles can be seen with GPS. What would happen if a vehicle/vehicles were in an area where GPS service is lacking or reception is inconsistent? This seems to be a critical element that was overlooked by the authors.

# Ad-Hoc Peer-to-Peer Network Architecture

Wai and Shengwei's (2005) approach to V2V communications research offers two unique local Ad-hoc peer-topeer groups (LPG) designs, Dynamic and Static. Static LPG is a stationary design, whereas Dynamic is constantly changing through the aid of RSU's. They modeled the design based off of an array data structure, which partitions the road into different sections Each section is assigned an element number to each section, or what the author refers to as zip codes. Dynamic LPG's are based off of the road/array implementation as well. However, this is a design that accommodates the agile needs of a network. Using single and multi hop methods, the authors introduce different dynamic customizations that focus on factors such as message directions, bandwidth, and multicasting issues.

Static LPG's are dependent upon stationary devices to propagate and receive messages. The same issues with GPS apply in this research, along with the effect that an increase in density of vehicles has on the consistency of

transmitting and receiving of messages. Attempting to account for these inconsistencies using GPS, they developed a more dynamic LPG. However, while eliminating the need for RSU's, the design became problematic with packet congestion. Throughput in multi-hop was reported to decrease randomly at times when the number of hops increased. MAC throughput limitations are due to the use of half duplex technology and its inability for a node to send and receive messages simultaneously.

This article allowed the problem to be looked at in a different way. With the design being that of a data structure, we were able to see a real world relation between the two. It is because of this particular article that an attempt to approach the problem using software.

# Cluster-Based Multi-Channel Communications Protocols

Zhang, Su, & Chen (2006) derived three protocols of their own that work together by forming a cluster-like configuration. The first protocol, "Cluster Configuration", groups all vehicles traveling in the same direction sharing similar speeds into clusters. Within each cluster, one is elected as the cluster-head (CH). The second protocol, "Intercluster Communication", dictates the transmission messages over two separate 802.11 MAC-channels. Finally, the third protocol, labeled "Intracluster Communication" respectively, defines the CHs responsibility, which includes the collecting and delivery of messages using upstream time division multiple access (TDMA) /downstream-broadcast method. This is accomplished using two transceivers simultaneously on three different channels. This CH sends messages to the whole cluster. While the CH is broadcasting to the whole cluster, cluster-members (CM) are also inter-communicating within themselves. If the CH is lost from a specific cluster, the election of a quasi-cluster-head (QCH) takes place until the CH is found or the time allotted on the counter times out. If the latter happens, then the QCH becomes the new CH.

These authors differ from the previous works reviewed in that the CH sends out an invite-to-join broadcast to other nodes using the time period that was defined by the authors. The relevance behind this case study to this research is the formation of a system's architecture and the election of a cluster-head. They also define a contingency plan in the case of a lost CH by their proposed finite state machine that is based off of 4 states and within these 4 states are definitions for CH, QCH, cluster member (CM), and finally quasi cluster member (QCM). This type of contingency is needed to help lower the breakage in node links that seem to plague VANETS high mobility factor.

# Cluster-based MAC

Mammu, Jayo, & Sainz (2013) attempted to design a new MAC protocol for VANETS, which they referred to as the DCBM (cluster-based MAC protocol). It provides reliability and message delivery during a given time limit, despite the density of incoming and outgoing vehicles in the network, while keeping the cluster stable. This scheme uses roadside units, assuming they are evenly spaced along the side of the road. The protocol incorporates three states that a vehicle can be in at any given time: cluster-head, cluster-member, and gateway vehicle. Every vehicle starts off as a gateway vehicle, which can be a cluster member of two different clusters, or be independent of any cluster. Upon joining a cluster, a vehicle becomes a cluster-member. If the cluster-member is elected as the CH, it gathers information from all the other cluster-members, which is transmitted to the RSU. This protocol creates overlapping networks that prevent gaps by quickly replacing the CH when the previous one has left the system.

Each of the articles reviewed present unique perspectives on V2V protocols. Most of the case study designs used RSU's for the propagation of messages to vehicles, and some used different technology like GPS. Others used geographic location and inter communication between vehicles in an agile-like formation of networks. Examining this particular group of articles has led us to believe that a solution to developing an efficient protocol for V2V communications could be best produced by merging all of the concepts proposed. An ideal system would be completely dependent on the vehicles themselves, and able to form modular network clusters independent of RSUs. These networks should have the ability to form self-regulating networks rapidly and keep up with the coming and going of mobile nodes.

#### **RESEARCH QUESTION**

From this literature review, the following questions started to arise: First, can these technologies be meshed together to create a more efficient VANET without the need for RSU's?

Second, can a splay tree data structure implementation assist in developing a more efficient cluster solution?

Finally, can these clusters be made to be both reconfigurable with bi directional communication?

#### THEORETICAL FRAMEWORK

#### Protocol Definitions

The foundation of this protocol is based off the following pieces of information that were vital in previous studies. From the article "Vehicle-to-Vehicle Safety Messaging in DSRC", the lifetime equation and quality of service (QOS) will be used to determine a transmission's useful time frame for this new protocol. The three state machine that is similar to the one mentioned in " Cluster-based MAC in VANETs for Safety Applications " will be used for the creation of clusters. These clusters will consist of (2^2nd)-1 nodes, and will join with other clusters to form a tree of clusters, independent of each other yet linked.

#### Software

OMNeT++ is an Eclipse-based open source developed integrated development environment (IDE) using C++ libraries for modular development in designing network protocols. It is currently being used for both academic and enterprise use around the world. The OMNeT++ IDE allows for the development of backend network functionalities and packages to be used by network simulators. Various networking frameworks have been built using OMNeT++. The two traffic simulation frameworks we will be using for simulations of the proposed protocol are Vehicles in Network Simulation (VEINS) and Simulation for Urban Mobility (SUMO). OMNeT++ also includes its GUI runtime environment of its own allowing for real time simulations when used in conjunction with similar networking frameworks.

The Internet Network framework (INET) that comes packaged with OMNeT++ allows for testing and creating network protocols. It comes equipped with already defined protocols such as DHCP, SCTP, STP, and RSTP. This framework also emulates the following network model layers: TCP/IP layer, Network layer, Data link layer, and MAC layers (both wired and wireless).

SUMO is a vehicle road traffic simulator that will allow us to emulate various traffic simulations. It supports both single and multi bidirectional traffic control. It has different vehicles to choose from and supports up to 100,000 separate vehicle route updates on a 1GHz machine. SUMO uses the standard C++ libraries. Given its front end designed GUI, SUMO is able to work with and in parallel to other network simulation tools and systems.

VEINS, a vehicular network simulator, depend on OMNeT++ for simulating the needed network protocols and SUMO for the graphical road traffic. Both of these programs run parallel to each other; when a vehicle is moving on SUMOS GUI the movement is reflected in OMNeT++ GUI. VEINS also has a third layer to its framework called Mixim. In short, Mixim is an OMNeT++ package with a focus on wireless simulations. Two particular models of importance are in the IEEE 802.11p model, and its DSRC/WAVE model. We will now give a description on the workings of our protocol.

#### METHODS

The following steps have been taken for the development of this project. After gathering the required pieces of software needed to simulate my project, I downloaded OMNeT++ version 4.2 was downloaded then opened up using the mingwenv terminal, were we proceeded to build the OMNeT++ project .The next step was to download and acquire both the SUMO and VEINS frameworks, and install them on our test machine.

#### RESULTS

The linking and running of the software has been successful. The author is currently working on the functionalities of all three software. Due to the time constraints and the scope of this project there were difficulties in implementing and obtaining the desired results for analysis.

#### DISCUSSION

A protocol that borrows certain elements from past research has been defined. It is hoped to achieve continuity amongst the nodes in a high mobile network environment. If this is successful, it can be used to not only alert human drivers, but may also be applied for military tactical purposes as well as autonomous vehicles. For future work, we plan to complete this current research, apply what is learnt from our results, and refine it to coincide with driverless vehicles. The design of this network protocol will be defined using pseudo code. Finally a module will then be implemented within OMNeT++. This process will be debugged for syntax errors. When the bugs are removed, the simulation will be run and the data analyzed to answer the aforementioned research questions.

LIST OF TERMS

ACK: Acknowledgement

CBT: Channel Busy Time

CDT: C/C++ Development Tools

CSMA/CA: Carrier Sense Multiple Access with Collision Avoidance

CTS: Clear to Send

Data Link Layer 2nd layer of OSI model

DHCP Dynamic Host control Protocol

DSRC: Dedicated Short Range Communication

FCC: Federal Communications Commission

GPS: Global Positioning System

**IDE:** Integrated Development Environment

#### LPG: Local Peer Group

- MAC Layer: Media Access Control Layer sub layer data link layer
- Network Layer 3rd layer of OSI model
- Node: Communicating Vehicle
- PRF: Probability of Reception Failure
- QOS: Quality of Service
- RTS: Ready to Send
- RSTP rapid spanning tree protocol
- **RSU:** Roadside Units
- SCTP Stream control transmission protocol
- STP: Spanning tree protocol
- SUMO: Simulation of Urban Mobility
- TCP/IP Layer: Transmission Control Protocol/ Internet Protocol
- VANETS: Vehicle Ad-Hoc Networks
- V2V: Vehicle-to-Vehicle
- WAVE: wireless access in vehicular environments

#### REFERENCES

- Chen, H., Zhang, X., & Su, H.(2006) Cluster-Based Multi-Channel Communications Protocols in Vehicle Ad Hoc Networks. *IEEE Wireless Communications*, 13, 44-51.
- Chen, W., & Cai, S. (2005)Ad Hoc Peer-to-Peer Network Architecture for Vehicle Safety communications. Communications Magazine, IEEE, 43, 100-107.
- What's a Network Protocol? Retrieved August 12, 2014. <u>http://compnetworking.about.com/od/networkprotocols/g/protocols.htm</u>
- Daniel Krajzewicz, Jakob Erdmann, Michael Behrisch, and Laura Bieker. Recent Development and Applications of SUMO - Simulation of Urban MObility. International Journal On Advances in Systems and Measurements, 5 (3&4):128-138, December 2012
- Dedicated Short Range Communications (DSRC) Service. Retrieved August 2, 2014, from http://wireless.fcc.gov/services/index.htm?job=service\_home&id=dedicated\_src
- <u>Christoph Sommer, Reinhard German</u> and <u>Falko Dressler</u>, "Bidirectionally Coupled Network and Road Traffic Simulation for Improved IVC Analysis," *IEEE Transactions on Mobile Computing*, vol. 10 (1), pp. 3-15, January 2011 Retrieved August 1, 2014, from <u>http://veins.car2x.org</u>
- INET (2012) INET Framework for OMNet++ Retrieved August 1, 2014, from http://inet.omnetpp.org/doc/INET/inet-manual-draft.pdf
- Korkmaz, G., Ozguner, F., Ekici, E., & Ozguner, U.(2004) Urban multi-hop broadcast protocol for inter-vehicle communication systems. VANET '04 Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks, 1, VANET '04.
- Mammu, A. K., Hernandez-Jayo, U., & Sainz, N.(2013) Cluster-based MAC in VANETs for Safety Applications. Advances in Computing, Communications and Informatics (ICACCI), 2013 International Conference on, 1424 1429.
- OMNeT++. (2014). *Network Simulation Framework*. Retrieved August 1, 2014, from http://www.omnetpp.org/documentation
- Xu, Q., Mak, T., Ko, J., & Sengupta, R. (2004)Vehicle-to-vehicle safety messaging in DSRC. VANET '04 Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks, 1, 19-28. Retrieved June 1, 2014, from
- Xu, Q., Sengupta, R., & Jiang, D.(2011) Design and Analysis of Highway Safety Communication Protocol in 5.9 GHz Dedicated Short Range Communication Spectrum. Ubiquitous Intelligence and Computing: Third International Conference, 2451-2455.

# COMPARISON OF R IMPLEMENTED TOPOLOGY-BASED PATHWAY ANALYSIS TOOLS USING TARGET PATHWAYS

By Alyssa Wilkins Major: Computer Science Mentors: Dr. Sorin Draghici, Department of Computer Science Ms. Cristina Mitrea, Department of Computer Science

#### ABSTRACT

Pathway analysis methods are used to derive hypothesis for important biological questions related to disease mechanisms, which helps molecular biologists solve important biological problems. The evaluation of new methods is a mandatory step in proving their efficacy and the existence of a benchmark is a necessity for this step. Different methods are implemented to run on a specific experiment data format and on specific pathway databases, which makes running multiple tools on the same input a challenging task. Recent work has provided a collection of benchmark biological experiment datasets, which was used to evaluate gene set analysis methods that do not consider the pathway topology. Here, we will evaluate a set of topology-based pathway analysis tools on the same datasets and discuss the results of our evaluation. We ran 7 pathway analysis tools on the same pathway describing it, which is called target pathway. We evaluated the tools based on the rank and p-value of the target pathway. Results show that there is little agreement between the tools and a lot of variance for the results of the same tool across multiple datasets. With this objective evaluation in place, we conclude there is room for improvement in pathway analysis.

#### **1** INTRODUCTION

Molecular biology is the understanding of the various interactions between biological mechanisms and their regulation. The fundamental concepts of molecular biology are the deoxyribonucleic acid (DNA), the ribonucleic acid (RNA) and proteins; which represent the three major life essential macromolecules. Proteins are fundamental components of all living cells. Various biochemical elements found in cells can be formed from proteins. They include hormones and antibodies, which are necessary for the proper functioning of an organism. Antibodies are used by the immune system to identify and neutralize hostile bacteria and viruses. Hormones transport a signal from one cell to another through blood to begin signal transduction. Proteins could not be produced without their code that is stored in the DNA. The DNA is a chemical compound, a molecule, 2 meters long that resides in the nuclei of mammalian cells. The DNA structure consists of nucleotides and a polymer. The nucleotide is comprised of a deoxyribose sugar, a phosphate group and a nitrogen base. The polymer serves as the backbone of the DNA that is comprised of alternating sugar and phosphate sequences. The DNA nitrogen base can be one of four: adenine, guanine, cytosine or thymine. The four bases are paired by complementarity: adenine pairs with thymine and cytosine pairs with guanine. Genes are functional stretches of DNA that contain the code for generating a polypeptide (protein). A gene is expressed when the protein it encodes is produced and repressed when the production is stopped. The RNA is a macromolecule complementary to a stretch of DNA, which performs important roles among which are the expression and repression of genes. The general flow of biological information is: DNA can be copied to DNA (replication), DNA information can be copied into messenger RNA (transcription), and proteins can be synthesized using the information from the messenger RNA as a template (translation) [11].

Biological studies that have been conducted have yielded information about the different systems present in the human body. Experiment data is stored in publicly available databases such as Gene Expression Omnibus (GEO) [3, 1]. One type of information we have knowledge of is differentially expressed (DE) genes or proteins. DE genes are significantly different between two phenotypes (condition vs. control). However, this information does not give investigators the insights of the biology of the condition being studied. Extracting useful meaning from the long list of DE genes and proteins proves to be a challenging task. One way to tackle this specific challenge is to reduce the long individual lists of genes to smaller sets of related genes or proteins. This reduces both the noise and the search space; however it does not make use of the important knowledge given by the interaction between genes.

Biological pathways are maps that describe how various cellular processes take place under different phenotypes. An example of a cellular process is insulin signaling. The genes in a specific pathway are more related to each other than to the ones on other pathways. A pathway can be defined as a set of genes and their interactions. Examples of such interactions are the before mentioned expression (activation) and repression (inhibition). These are actions that the product of a gene can perform on another gene. Pathways are stored in publicly available databases such as the Kyoto Encyclopedia of Genes and Genomes (KEGG) [7, 8], REACTOME, or NCI DBI. It is important to know which process is significantly disrupted in a specific biological condition so that accurate steps are taken towards restoring cellular function. Pathway analysis methods are used to derive hypothesis for these questions. To identify the disruption, samples taken for the condition (disease) are compared with samples taken for a control (healthy). During a biological experiment, the level of different cellular elements such as genes proteins, or metabolites can be measured in both disease and control. Pathway analysis uses the measurements of cellular elements and a set of biological pathways and returns a ranked list of pathways with associated p-values. In this list, the higher a pathway is, the more significant is the pathway disruption.

Khatri et al. [10] categorized pathway analysis tools into three main categories. The first generation is comprised of tools that perform an enrichment analysis. The genes evaluated are those showing a change in expression. Second generation tools are an improvement over first generation methods, by taking into consideration the correlation of each gene with the phenotype under study. Small changes in individual genes can have significant effects on pathways. Also, coordinated changes in functionally related genes can trigger changes that significantly affect pathways. The third generation tools include the pathway topology in the computation of significant pathways for a given data set.

Mitrea et al. [14] presents a comprehensive survey of 22 topology-based pathway analysis methods. This survey compares and contrasts the mathematical model used in these methods, from ratios of the condition and control values to probabilistic models. The structures used to store pathway data are also discussed, and different types of graphs are used for this purpose such as: undirected, directed graphs with one type of node or graphs with multiple types of node. Important milestones in topology-based pathway analysis are mentioned and can be summarized as follows: the first method developed for metabolic networks [15], the first method developed for signaling pathways [9,2], the first method that applies topology-based multivariate hypothesis tests [17] and the first method based on graphs that accept different node types [20].

A recent study takes the first step forward in providing a set of 24 benchmark datasets for gene set analysis methods [18]. Conversely, for each of these datasets, there is only one target pathway selected. The target pathway selected is based on the phenomena under study, e.g colorectal cancer. Such phenomena are generic and the mechanism may not be limited to the specific pathway. Another recent study [16] tries to unify several pathway analysis methods in a single R package. Nevertheless, the methods were run on different experiment datasets and different pathway databases. Researchers face a great challenge in validating new pathway analysis methods. When given a set of pathways and gene expression data comparing disease with control is used, there is no objective way to determine which analysis is better at finding significant pathways. Uniformity of data

would allow the use of different organisms. Some experiments are best suited for a specific organism. For example, knockout experiments are highly unlikely to be performed in vivo in humans; however they are readily performed in mice. Having such standards and benchmarks will allow comparisons to find the analysis methods to further accuracy, precision, and reliability.

Tools Name	Abbreviation	Version	Availability
Centrality-based Pathway enrichment	CePa	0.5	CRAN
Clipper	Clipper	1.2.3	bioconductor
DEgraph	DEgraph	1.14.0	bioconductor
Gene Association Network-based Pathway Analysis	GANPA	1.0	CRAN
R Onto-Tools suite	ROntoTools	1.2.0	bioconductor
Signaling Pathway Impact Analysis	SPIA	2.14.0	bioconductor
Topology Gene Set Analysis	TopologyGSA	1.4.3	bioconductor

**Table 1.** Topology-based analysis tools compared in this study providing the name of the tool, its version in R and where the tool is available to download.

#### 2 Methods

#### 2.1 Centrality-based Pathway enrichment (CePa)

Gu et al. [5] proposes CePa, a tool that is a pathway enrichment method based on gene weighting that finds significant pathways using topology information. There are two improvements over the gene set weighting methods previously developed. The first improvement is that the user can specify the method by which the network node would be weighted. The second improvement is that nodes do not have to represent only single genes but also complexes and protein families. The authors of CePa extend two previously developed enrichment methods by assigning network centralities as node weights. Given a biological experiment, the input for CePa is: the list of differential genes, the list of all measured genes, a list of pathways with their topology, the method to compute node scores and the method to aggregate node scores to pathway level. The list of differential genes and list of background genes must contain a gene identifier for each gene, which can be either the gene symbol or RefSeq ID. Using the gene identifier, CePa maps the genes to nodes. Keep in mind that pathways can contain non-gene elements, such as metabolites or microRNAs. Next, several centrality measures are selected and their values are computed. The equations used for the centrality measures are: in-degree,  $C^{in}(v) = max\{d(w,v)\}$  and out-degree,  $C^{out}(v) = max\{(v,w)\}$ , where d(w,v) is defined as the length of the shortest path between the nodes v and w. Next, nodes are weighed by the centrality measure and aggregated to pathwaylevel. The equation of the pathway score is  $s = \sum w_i d_i$ , where  $d_i$  identifies whether the  $i^{th}$  gene in the pathway is differentially expressed or not and  $w_i$  is the weight of that gene based on the centrality measure. If there is a simulation, these steps are repeated with permuted labels for genes, for the number of times the user specifies, which will generate the null distribution of the pathway-level scores. Finally, the p-values for the pathway-level scores are computed based on where the pathway score falls on the null distribution. The output of CePa is a list of pathways and their associated p-values.

#### 2.2 Clipper

Martini et al. [12] divides gene set enrichment methods in two categories: i) methods based on enrichment analysis preformed on a list of genes that have been selected through a gene level test and ii) methods based on global and multivariate probabilistic approaches that define a model on the whole gene set. The two approaches are based on different null hypotheses. The first method hypothesizes that the level of association of a gene sets with a given phenotype is the same as for the complement of the gene set. The second approach hypothesizes that there is no gene set associated with the phenotype. Clipper is an empirical two step method that identifies

significant signal transduction paths that are within significantly altered pathways. Clipper agrees with the hypothesis that phenotype is present in the pathway. The input of clipper is gene expression data and a set of pathways. First, clipper tests the whole pathway and identifies the signal pathways significantly different between the phenotype under study and a control phenotype. This is done by using two graphical Gaussian models:  $M_{1=}\{Y \sim N_p \ (\mu_1, \sum_l), K_l = \sum \mathcal{E} S^+(G)\}$  and  $M_{2=}\{Y \sim N_p \ (\mu_2, \sum_l), K_l = \sum \mathcal{E} S^+(G)\}$ , where p represents the number of genes or the vertices of the pathway graph G,  $K_1$  and  $K_2$  represent the concentration matrices or inverse of the covariance matrices of the two models, and  $S^+(G)$  represents the set of symmetric positive definite matrices that have null elements that correspond to the missing edges of G. The null hypothesis to test the strength of the links between genes is  $H_0:K_1 = K_2$ , where the working hypothesis is  $H_1:K_1 \neq K_2$ . The null hypothesis to test for the differential expressions of a pathway is  $H_0$ :  $\mu_1 = \mu_2$ , where the working hypothesis is  $H_1$ :  $\mu_1 \neq \mu_2$ . Once the graph G is known, the null elements in the concentration matrices can be identified. The unknown variables  $\mu_1$ ,  $\mu_2$ ,  $\sum_1$  and  $\sum_2$  need to estimated.  $\sum_1$  and  $\sum_2$  can be estimated by using the Iterative Proportional Scaling algorithm. The sample covariance matrices are the starting values for the algorithm. Clipper applies a shrinking procedure to estimate the covariance matrix. The second step is to identify relevant signal paths. Pathways are transformed into junction trees that serve as a backbone for clipper to empirically identify portions of the tree that are associated with the phenotype. Paths and sub-paths can be highly overlapping; therefore clipper implements a procedure that uses a cluster analysis approach to remove the overlap. The output is a list of significant pathways.

#### 2.3 DEgraph

DEgraph is a pathway analysis method developed by Jacob et al. [6], that uses a two sample graph test that takes in account the graph structure. According to the authors of DEgraph the shifts in expression levels of the differentially expressed genes are expected to be coherent with the structure of graphs reflecting the following gene properties: biological process, molecular function, regulation or metabolism. Considering the graph structure as part of the analysis is important because it can be used to detect systemic changes between two conditions. An application could be to compare samples from patients who are receiving an effective treatment for a condition with samples from patients who are resistant to the treatment. Insight about the resistance mechanisms of the condition could be used to create treatments to target the resistance. DEgraph input is gene expression data and a list of pathways. Then, the Hotelling T<sup>2</sup>-test is applied in the new graph-based space. Next, the unadjusted pathway p-values are computed under nominal F-distributions. Lastly, the Benjamin and Hochberg procedure is applied to control the false discovery rate (FDR). The output data frame is a list of significant pathways with their p-values and a list of generated errors.

#### 2.4 Gene Association Network-based Pathway Analysis (GANPA)

GANPA is a method developed by Fang et al [4] that proposes to use gene weights when identifying significant pathways. According to the authors of GANPA, there are shortcomings in reducing gene pathways to gene sets. Functional interactions among genes are ignored and all genes are treated equally. Gene sets do not represent true biological pathways since there are genes that are more important than others in the pathway. GANPA is based on protein-protein interactions, co-annotations and co-expressions collected from public databases, which are used to assign weights to the pathway genes. The computed gene weights can also be used in the classical gene set analysis pipelines. The input for GANPA is p53 data from GSEA website, protein-protein interactions from several websites such as BioGrid or Reactome, and co-expressions data collected from 73 human gene expression datasets from NCBI GEO. The analysis also uses co-annotations, which match the gene pairs that share one lowest-level biological process term in the hierarchy graph of gene ontology. All these association data is used to construct an association network. The algorithm of GANPA computes a pathway statistic that contains both the pathway structural information as well as the gene expression changes. This statistic is computed as an enrichment score of the pathway genes in the association network. The output of GANPA is written to an excel file that contains the list of pathways with associated p-values, and other pathway statistics.

Signaling Pathway Impact Analysis (SPIA) is an analysis method that is a variation of its predecessor called impact analysis [2]. Impact analysis was created as an improvement to methods such as over-representation analysis (ORA) and the gene set enrichment analysis (GSEA). ORA and GSEA are methods that treat the pathways as simple sets of genes. The complex gene interactions that the pathways described were not considered in these methods. Tarca et al. [19] demonstrates that SPIA combines two types of evidence. The evidence is over-representation of differentially expressed genes in a pathway and the perturbation of gene expression change through that pathway. The input of the SPIA method is the log2 fold changes of the differentially expressed (DE) genes, a list of all the genes measured during the experiment, a list of pathways described by connectivity matrices, and the organism symbol. The fold change for a gene is the ratio of disease (condition) over normal (control). The list of pathways is represented by the signaling pathways from KEGG. The connectivity matrices are the genes in the rows and columns and an element of the matrix can be 1 if the genes interact or 0 if the genes do not interact. With these inputs, the tool computes the gene perturbation factors. The equation of the gene perturbation is  $PF(g_i) = \Delta E(g_i) + \sum_{u=1}^{n} \beta_{iu} \times (PF(g_u)/N_{ds}(g_u))$ , where  $\Delta E(g_i)$  is the change in expression for gene *i*,  $\beta_{iu}$  gives the type and strength of the interaction between genes *i* and *u* (1 for activation, -1 for repression),  $g_u$  is a gene upstream gene *i* in the pathway, and  $N_{ds}(g_u)$  is the number of downstream genes for  $g_u$ . To compute the results for SPIA, first, the gene perturbation accumulation is computed with  $Acc(g_i) = PF(g_i) - \Delta E(g_i)$ . The subtraction in the accumulation is so the DE genes are not considered twice in the calculation of pathway significance. The accumulation equation is written for each gene in the pathway and the system of equations is solved, providing a pathway accumulation by summing the accumulation of all genes in the pathway. The second step is to use a bootstrap procedure to compute the significance of pathway accumulation with the equation  $P_{PERT} = P(T_A \ge t_A / H_0)$ . In the third step, the tool performs the hypergeometric test to assess how likely it is to have the observed number DE genes in a pathway just by chance. The last step is to combine the two types of evidence in a global p-value. This is a combination of p-values from the two types of evidence. The formulas used to combine them are  $P_G = c_i \times ln(c_i)$  and  $c_i = P_{NDE}$  $\times P_{PERT}(i)$  for each pathway *i*. The output is a data frame containing the following columns: pSize, NDE, tA, pNDE, pPERT, pG, pGFdr, pGFWER, STATUS and KEGGLINK in the file. The pSize column is the number of genes of the pathway. The NDE column is the number of DE genes per pathway. The total perturbation accumulation in the pathway is the column tA. pPERT column is the probability of observing total accumulation more extreme that tA by chance. The column pG is the p-value that is obtained from the combination of pNDE and pPERT equations. pGFdr and pGFWER are the columns that are the False Discovery Rate and Bonferroni adjusted global p-values. The STATUS column gives the direction of the pathway is perturbed (activated or inhibited.) The last column, KEGGLINK, provides a web link to the pathway image, from the KEGG website, with DE genes marked in red for over-expression and green for under-expression.

#### 2.6 R Onto-Tools suite

R Onto-Tools suite (ROntoTools) is a topology-based pathway analysis tool proposed by Voichita et al.[21] that includes variations of pathway impact analysis. ROntoTools incorporates the significance (p-value) of each gene. This allows genes that are more significant to be weighted more than the ones that are less significant, which may provide an accurate assessment for the pathway perturbation by reducing the noise without losing important information. Therefore, the whole list of measured genes could be used in the analysis without a preliminary gene selection. Preliminary selection depends on a chosen threshold. Different methods could have different threshold values and the results would reflect this. The input ROntoTools is the list of differentially expressed (DE) genes (IDs and log fold change, here we may use the list of all genes), list of all genes entrez IDs, and the list of pathways. ROntoTools has five steps to compute the results. The first step in the ROntoTools algorithm is to compute the gene perturbation factor using the formula  $PF(g) = \alpha_g \times \Delta E(g) + \sum \beta_{ug} \times PF(u)/$  $N_{ds}(u)$ , for each pathway gene g. Here, the significance value for the measured expression change of a gene g is computed with the formula:  $\alpha_g = 1 - (P_g/\alpha_t)$ , where  $\alpha_t$  is the significance threshold used for the selection of DE genes. The second step of ROntoTools is to compute the pathway accumulation using the formula  $Acc(g_i) = PF(g_i) - \alpha \times \Delta E(g_i)$ . The third step is to use a bootstrap procedure to compute the significance of pathway accumulation  $P_{PERT} = P(T_A \ge t_A / H_0)$ . The fourth step is to perform the hypergeometric test to assess how likely it is to have the observed number of DE genes in a pathway just by chance. The last step is to combine the two types of evidence in a global p-value a combination of p-values from the two types of evidence using  $P_{G(i)} = c_i \times ln(c_i)$  and  $c_i = P_{NDE} \times P_{PERT}(i)$  for each pathway *i*. The output for ROntoTools is a data frame with the following columns: totalAcc, totalPert, totalAccNorm, totalPertNorm, pPert, pAcc, pORA, pComb, pPERT.fdr, pACC.fdr, and pComb.fdr. The first column totalAcc is the value of total accumulation. The totalPert column contains the values of the total perturbation. The totalAccNorm and totalPertNorm are the columns that have been normalized using bootstrap. The pPert column stores the significance of the total perturbation after bootstrap permutations. The pAcc column stores the p-values computed using the number of DE genes and the hypergeometric formula. The pComb column contains the combination of p-values. pPERT.fdr, pACC.fdr, and pComb.fdr are the columns that have False Discovery Rate applied to the values in the pPert, pAcc, and pComb columns.

#### 2.7 Topology Gene Set Analysis (topologyGSA)

Massa et al. [13] propose topologyGSA a pathway analysis designed to study the behavior of pathways within a graphical model context, thin a graphical model context, the data is considered coming from a Gaussian multivariate distribution. This has a structured concentration matrix that reflects the dependencies among variables. The authors of topologyGSA present two statistical tests for comparing gene sets under different experimental conditions. The first test addresses whether strength of the connections among genes are altered in different experimental condition. The second test is designed to test for differential expression within a pathway. The input for topologyGSA is a gene expression dataset and a set of pathways. The first step for topologyGSA is to convert a pathway into a graphical model. The structure of the pathway is converted into a directed acyclic graph D as follows. First, inhibition, phosphorylation and dephosphorylation are considered simple directed edges. Second, any undirected edges are given a direction by using information from Biocarta pathway database. Then D is converted into a moral graph  $D^m$  by adding edges between the parents of each vertex and directionality of the original edges removed. The second step is testing if the pathways change between different experimental conditions. The third step is to test the equality of the strength among genes. The output of topologyGSA is a list of pathways and associated p-values.

#### 3 MEASURES FOR THE PERFORMANCE ASSESSMENT

We ran the pathway analysis tools on the same pathway database (KEGG) and on multiple target pathway experiment datasets. To evaluate, we use the position of the target pathway in the resulted ranked list and the p-value associated with the target pathway. The lower is the rank of the target pathway the more accurate the method is in identifying disrupted pathways. Similarly, a more accurate method will provide a lower p-value for the target pathway.

#### 4 RESULTS

We ran 7 pathway analysis tools on the same pathway database (KEGG) and on 24 experiment datasets. We provide box plots for all 7 tools for both the ranks of the target pathways and the p-values (Figures 1 and 2). The tools that report an empty set of results, DEGraph and GANPA the target pathway is not the ranked list returned by the method, a close observation reveals that no pathways with IDs over 05000 are returned by these methods and all target pathways in this study have such IDs (see Appendixes for the list of datasets and target pathways). There were two other tools we tried to compare: clipper and topologyGSA. We report that for clipper no p-values or ranks were provided, but a collection of significant pathways, therefore we could not perform the comparison. For topologyGSA running it for a dataset over all pathways (around 150 pathways) would not end for several hours on a MacBookPro with default resources, therefore we will use it in a future comparison.



**Figure 1.** Results on the comparison of 7 pathway analysis tools (x-axis) based on the normalized ranks of target pathways for 24 datasets (y-axis).



**Figure 2.** Results on the comparison of 7 pathway analysis tools (x-axis) based on the p-values of target pathways for 24 datasets (y-axis). The lower the p-value the more significant is the perturbation of the target pathway.

#### **5** DISCUSSION AND CONCLUSIONS

A challenge faced when running the multiple analysis tools on the same dataset is that there are different pathway databases in the default implementation of each tool. Different databases such as KEGG, REACTOME, NCI-PID, and others, were used in different formats and loaded into different data structures. There is no ready to use conversion from one format to another, therefore additional effort is required to either modify the format of the input pathway database or change the algorithm to accommodate the existing format of a new database. An example of a conversion method can be seen below.

```
timestamp=Sys.Date(),
database="KEGG")
return(mypathway)
```

The object mygraphNEL is a list object that has the name of the pathway and the graphNEL object containing the pathway information.

For a thorough evaluation we use 24 datasets that study different diseases. These datasets summarize 12 different conditions from three different categories of diseases (Table 2). We list all of these with a short description. The first three diseases are in the neurodegenerative category. Neurodegenerative diseases are marked by the progressive loss of function or structure neurons in the brain. The death of neurons is also included in neurodegeneration. The neurodegeneration can occur on the molecular or systemic in the various neuronal circuitries. Cancer is a group of diseases that involve the growth of abnormal cells that have the ability to spread in the body. The spreading of cancer is called metastasis. Metastasis can occur through a local spread, lymphatic spread from the local lymph nodes to regional lymph nodes and blood. Cancer can also be known as malignant tumor. Heart disease is the description of various conditions that affect the heart. The diseases that listed as heart diseases are blood vessel diseases, rhythm problems and heart defects a person can be born with. The term heart disease can be substituted with cardiovascular disease.

Neurodegenerative Diseases	Description
Alzheimer's Disease	Loss of memory and other intellectual abilities
Parkinson's Disease	Loss of motor functions
Huntington's Disease	Loss of muscle coordination
Cancer	
Colorectal Cancer	Cancer of the rectum/colon
Renal Cancer	Cancer of the kidneys
Pancreatic Cancer	Cancer of the pancreas
Glioma	Cancer of the brain/spine
Prostate Cancer	Cancer of the prostate
Thyroid Cancer	Cancer of the thyroid
Acute myeloid leukemia	Cancer of bone marrow/blood
Non-small Cell Lung Cancer	Cancer of the lungs
Heart Disease	
Dilated cardiomyopathy	Abnormal expansion of the heart muscles

Table 2: The 12 different diseases of the datasets and their description.

Results show that there is little agreement between the tools, which can be due to the noise in the data. This may be one of the reasons the all gene approach (boxplot 3 in Figures 1 and 2) provides lower quality results. There is also a lot of variance for the results of the same tool across multiple datasets (Figures 1, boxplots 2 and 3, Figure 2, boxplots 3 and 5). This may be caused by the lack of robustness in the algorithm, or the variability in the data and the complexity of the pathways. The best results seem to be reported by SPIA for ranks (Figure 1, plot 1), and CePaGSA for p-values (Figure 2, plot 6). We should keep in mind that the pathways are only a representation of our current knowledge of the specific biological processes.

There is always room for improvement in the evaluation method as well, the normalized rank may not be the best measure, rank 3/10 or rank 3/100 should not be an order of magnitude different. Even more so, the method that only reports 10 pathways might do a better job filtering the noise. Considering the objective evaluation presented in this study and out results, we conclude that there is room for improvement in pathway analysis.

#### **6** References

- 1. Barrett, Tanya, Stephen E. Wilhite, Pierre Ledoux, Carlos Evangelista, Irene F. Kim, Maxim Tomashevsky, Kimberly A. Marshall et al. "NCBI GEO: archive for functional genomics data sets—update." *Nucleic Acids Research* 41.D1 (2013): D991-D995.
- Draghici, Sorin, Purvesh Khatri, Adi L Tarca, Kashyap Amin, Arina Done, Calin Voichita, Constantin Georgescu, and Roberto Romero. "A systems biology approach for pathway level analysis." *Genome Research* 17.10 (2007): 1537-1545.
- 3. Edgar, Ron, Michael Domrachev, and Alex E. Lash. "Gene Expression Omnibus: NCBI gene expression and hybridization array data repository." *Nucleic Acids Research* 30.1 (2002): 207-210.
- 4. Fang, Zhaoyuan, Weidong Tian, and Hongbin Ji. "A network-based gene-weighting approach for pathway analysis." *Cell Research* 22.3 (2011): 565-580.
- 5. Gu, Zuguang, et al. "Centrality-based pathway enrichment: a systematic approach for finding significant pathways dominated by key genes." *BMC Systems Biology* 6.1 (2012): 56.
- 6. Jacob, Laurent, Pierre Neuvial, and Sandrine Dudoit. "Gains in power from structured two-sample tests of means on graphs." *arXiv preprint arXiv:1009.5173* (2010).
- 7. Kanehisa, Minoru, et al. "KEGG for integration and interpretation of large-scale molecular datasets." *Nucleic Acids Research* (2011): gkr988.
- 8. Kanehisa, Minoru, and Susumu Goto. "KEGG: Kyoto encyclopedia of genes and genomes." *Nucleic Acids Research* 28.1 (2000): 27-30.
- 9. Khatri, Purvesh, et al. "Recent additions and improvements to the Onto-Tools." *Nucleic Acids Research* 33.suppl 2 (2005): W762-W765.
- 10. Khatri, Purvesh, Marina Sirota, and Atul J. Butte. "Ten years of pathway analysis: current approaches and outstanding challenges." *PLoS Computational Biology* 8.2 (2012): e1002375.
- 11. Lodish. "Molecular Cell Biology" (2012)
- 12. Martini, Paolo, et al. "Along signal paths: an empirical gene set approach exploiting pathway topology." *Nucleic Acids Research* 41.1 (2013): e19-e19.
- 13. Massa, Maria S., Monica Chiogna, and Chiara Romualdi. "Gene set analysis exploiting the topology of a pathway." *BMC Systems Biology* 4.1 (2010): 121.
- 14. Mitrea, Cristina, Zeinab Taghavi, Behzad Bokanizad, Samer Hanoudi, Rebecca Tagett, Michele Donato, Călin Voichița, and Sorin Drăghici. "Methods and approaches in the topology-based analysis of biological pathways." *Frontiers in physiology* 4 (2013).
- 15. Rahnenführer, Jörg, et al. "Calculating the statistical significance of changes in pathway activity from gene expression data." *Statistical Applications in Genetics and Molecular Biology* 3.1 (2004).
- 16. Sales, Gabriele, et al. "graphite-a Bioconductor package to convert pathway topology to gene network." *BMC Bioinformatics* 13.1 (2012): 20.
- 17. Shojaie, Ali, and George Michailidis. "Analysis of gene sets based on the underlying regulatory network." *Journal of Computational Biology* 16.3 (2009): 407-426.
- 18. Tarca, Adi L, et al. "Down-weighting overlapping genes improves gene set analysis." *BMC Bioinformatics* 13.1 (2012): 136.
- 19. Tarca, Adi L, et al. "A novel signaling pathway impact analysis." Bioinformatics 25.1 (2009): 75-82.
- 20. Vaske, Charles J, et al. "Inference of patient-specific pathway activities from multi-dimensional cancer genomics data using PARADIGM." *Bioinformatics* 26.12 (2010): i237-i245.
- 21. Voichita, Calin, Michele Donato, and Sorin Draghici. "Incorporating gene significance in the impact analysis of signaling pathways." *Machine Learning and Applications (ICMLA), 2012 11th International Conference on.* Vol. 1. IEEE, 2012.

#### 7 APPENDICES

The table below is a summary of the conditions used to generate the 24 datasets we analyzed in this study.

Neurodegenerative Diseases	Name of target pathway	KEGG ID
Alzheimer's Disease	Alzheimer's Disease	hsa 05010
Parkinson's Disease	Parkinson's Disease	hsa 05012
Huntington's Disease	Huntington's Disease	hsa 05016
Cancer		
Colorectal Cancer	Colorectal Cancer	hsa 05210
Renal Cancer	Renal Cell Carcinoma	hsa 05211
Pancreatic Cancer	Pancreatic Cancer	hsa 05212
Glioma	Glioma	hsa 05214
Prostate Cancer	Prostate Cancer	hsa 05215
Thyroid Cancer	Thyroid Cancer	hsa 05216
Acute myeloid leukemia	Acute myeloid leukemia	hsa 05221
Non-small Cell Lung Cancer	Non-small Cell Lung Cancer	hsa 05223
Heart Disease		
Dilated cardiomyopathy	Dilated cardiomyopathy	hsa 05414

**Table 3:** Annotation of the different diseases, name of the target pathway and its respective ID in the Kyoto

 Encyclopedia of Genes and Genomes database.

The table below lists the GEO ID of the datasets, the target pathway of each database and its respective ID in the Kyoto Encyclopedia of Genes and Genomes (KEGG) pathway database.

GEO ID	Target Pathway	KEGG ID
GSE1297	Alzheimer's Disease	hsa05010
GSE5281	Alzheimer's Disease	hsa05010
GSE5281	Alzheimer's Disease	hsa05010
GSE20153	Parkinson's Disease	hsa05012
GSE8762	Huntington's Disease	hsa05016
GSE4107	Colorectal Cancer	hsa05210
GSE8671	Colorectal Cancer	hsa05210
GSE9348	Colorectal Cancer	hsa05210
GSE14762	Renal Cancer	hsa05211
GSE781	Renal Cancer	hsa05211
GSE15471	Pancreatic Cancer	hsa05212
GSE16515	Pancreatic Cancer	hsa05212
GSE19728	Glioma	hsa05214
GSE21354	Glioma	hsa05214
GSE6956	Prostate Cancer	hsa05215
GSE6956	Prostate Cancer	hsa05215
GSE3478	Thyroid Cancer	hsa05216
GSE3678	Thyroid Cancer	hsa05216
GSE9476	Acute myeloid leukemia	hsa05221
GSE18842	Non-small Cell Lung Cancer	hsa05223
GSE19188	Non-small Cell Lung Cancer	hsa05223
GSE3585	Dilated cardiomyopathy	hsa05414

**Table 4.** Table of the 24 target pathway datasets used in this study.

# ENHANCING LIQUID LENS USING ELECTROWETTING AND GRAPHENE MATERIAL

By Camille Williams Major: Engineering Mentor: Dr. Mark Cheng, Department of Electrical and Computer Engineering

#### ABSTRACT

This study examines how to enhance liquid lens using a multiphysical simulation software called COMSOL. Liquid lenses have become an important device for a wide range of new technology. The purpose of this study is to come up with new devices and applications for tunable lens in small cameras and maybe laptop webcams. This new feature will give laptops an upgrade, where the current webcam has a limited focus range. The literature discusses what liquid lenses are, the process of electrowetting on dielectric, what is graphene, and how to apply voltage to tune the shape of a water droplet. This will give background on the process of how to make liquid lenses. From the literature review and discussions with my mentor Dr. Cheng, I hypothesized that the software simulation will guide the experimental design. The data for the comparisons will be collected by using COMSOL and conducting experiments. The contact angle change of a water droplet in the process of electrowetting on dielectric using a transparent electrode graphene is simulated. This information is a key factor in conducting the software simulation for this particular study. *Keywords*: Electrowetting, Graphene, Liquid Lens, COMSOL

Liquid lens uses two properties of liquids within a confined space to provide magnification. This device became important for new technology such as cell phone cameras, and other small digital cameras. Liquid lens makes digital cameras appear crystal clear. In order to create a functional liquid lens, the two properties of liquids cannot mix upon introduction. This research focuses on how to change the variable focus length of the contact angle of a liquid lens. This would open new doors for liquid lens. If the focus length of the contact angle

changes, liquid lens could maybe be used for laptop webcams.

Electrowetting on dielectric is a way "to control and maintain liquid lens shape and its position by applying potential between electrodes and ground through the conductive liquid" (Zeidabadi, 2012) with using a type of insulator and a material called Graphene. Graphene is a new material of a single layer of carbon atoms that have been recently discovered in 2004. This opens new doors for new opportunities for liquid lens. The electrowetting process will help change the focal length of the contact angle. Studies that were reviewed (Zeidabadi, 2012; Cheng, 2012) gave an insight into liquid lens and the process of Electrowetting on Dielectric using graphene. These articles gave great detail on how to conduct the live experiments. However, there was not enough information on how to construct a simulation to predict live experiments. The problem is to see if the simulation matches the live experiments which this study will attempt to answer.

Something that was missing from prior studies was a detailed information on COMSOL Multiphysics software. The use of this software is very important to the experiment. I intend to use COMSOL to simulate different case scenarios to predict how the live experiment would run, such as a water droplet with voltage applied to the contact angle. The significance of this study is in using the software will help pushed liquid lenses to be used for other smaller camera devices such as webcams on laptops. This paper includes multiple sections that describe the experimental process for testing my hypothesis that the software simulation will match with the live experiment. The first section explores the procedure of the software to simulate a water droplet with voltage applied on both sides. The third section explores the procedure of the software to simulate the exact same device as in the live experiment. Then it will conclude with a comparison of the simulation with the live experiment.

#### PURPOSE STATEMENT

The purpose of this study is to describe the simulation of COMSOL and compare to the live experiment of electrowetting on dielectric using graphene for a liquid lens at Wayne Student University in the College of Engineering.

The following are the experiments conducted in COMSOL:

- Case 1: Water droplet with voltage applied on the contact angle
- Case 2: Water droplet with voltage applied on both sides
- Case 3: The exact same device as in the live experiment

The problem is to see if the simulation matches the case scenarios' live experiment.

#### HYPOTHESIS

The simulation of the software COMSOL Multiphysics, will match with the data gathered from the live laboratory experiment by using graphene in electrowetting on dielectric. The following are the variables used in this study:

- Independent Variable: Graphene is a material made of a single layer of carbon atoms
- Dependent Variable: Time Dependent Interphase in COMSOL Multiphysics
- Control Variable: Electrowetting on Dielectric is the modification of a contact angle of a liquid on a surface with an applied electric field.

#### THEORETICAL FRAMEWORK

In the literature review, Zeidabadi (2012) discussed the process of making liquid lenses under electrowetting. In order to make a liquid lens, you need a transparent substrate. This is important because you need to be able to see through the lens. You also need a thin, transparent conductive layer, a transparent dielectric layer, and a transparent hydrophobic layer. You do not want the liquid lens to be hydrophilic since the water droplet needs to stay on the surface and not sink through. This is why I am adopting Zeidabadi (2012) process because there is a specific order in conducting the experiment for the fabrication of liquid lens.

The assumption is that the protocol for the live experiment is correct, so, my team used the same procedures for the live experiment. My team chose the Liftoff process and the only thing that was different was growing graphene to put on top of the substrate. I found the problem is that the live experiment does not give a simulation of the results beforehand. My part of the experiment is to use the software COMSOL Multiphysics to simulate to predict what will happen in the live experiment. COMSOL was mentioned in some articles as the first step before conducting experiments. So, my rationale is to simulate COMSOL and test the results to see if it matches with the live experiment.

#### LITERATURE REVIEW

This literature review is used to find information already discussed about liquid lens and the process of changing the contact angle. The following are different articles from other scholars who did research on this particular subject. Their ideas helped determine my plans for research this summer. The next step is to see what I can do to enhance their ideas.

According to Petersen (2014), he describes a liquid lens using properties of two different liquids within a confined space to provide magnification. He also lists the benefits of liquid lenses, such as cell phone cameras, and other small digital cameras. These devices are of benefit because the water makes the lenses appear flawless. For my research, a graduate student and I are trying to enhance liquid lenses. To create a liquid lens,

we need two liquids that do not mix upon introduction and indefinitely. It is necessary to create a magnification that will change the variable focus of the liquid lenses. Petersen (2014) did not go into much detail of the process of magnification. So, I need to find more sources.

I agree with Petersen (2014) that liquid lenses are a great device for the future. The author even believes that it is possible to have every laptop produced to come with a built in webcam made from a liquid lens. However, another point of view that I thought was interesting was he talked about the disadvantages of liquid lenses. All the other articles left out the potential problems with liquid lenses. Petersen (2014) stated that the liquid lens should not be exposed to cold temperatures for a long time or it would cause the water to freeze. It is important to know the disadvantages as well as the advantages so we do not make mistakes during the experiment.

Dr. Cheng (2012), an Electrical and Computer Engineering professor, wrote an article on Electrowetting on dielectric using Graphene. He described graphene a single layer of carbon atoms. He described the process of growing graphene and the process of electrowetting on dielectric. For my research, I am working under Dr. Cheng and we had already been in touch when he wrote his article. So, I'm continuing where he left off. We will be following in his footsteps in order to improve on his research and seek out further and/or addition applications.

From Dr. Cheng's (2012) PowerPoint presentation on graphene, it shows an atomic thick planar sheet of carbon atoms. It has a high electron mobility of approximately 200,000 cm<sup>2</sup>/Vs. It is a low-cost, transparent electrode. This material is fairly new since it was discovered in 2004. So graphene was not a popular material until now. It is very strong and flexible after fabrication. It can store energy and is very small. This particular presentation is beneficial because it is good to know what graphene can be used for and its properties. Graphene is hydrophobic, which means that water can run off and not be absorbed in the material. Now, we know more about graphene in general.

Since, I have been working with Dr. Cheng (2012), I found that our viewpoints are similar to both of his articles. We both agree that graphene has not been investigated further for manipulation of droplets and electrowetting. Through our research, we hope to figure this out and open new doors for application, including flexible displays and droplet manipulation in three-dimensional microfluidics. My research team is using the same procedure that he did, we plan to change few steps to see if they would make any changes, like working more on the software part to come up with a better hypothesis.

In the article by Zeidabadi (2012), he described the process of making liquid lenses based on the concept of electrowetting. For my research, I am using this process to change the shape of the water droplet when it comes in contact with liquid lenses. This will cause a change in focal length as well. This is very important because this can enhance liquid lenses for new applications. The interesting part about this article is that Zeidabadi (2012) had the same goal as we do, which is to control the contact of a drop on liquid lenses. Our research team used the same procedure as Zeidabadi (2012) to achieve the goal of enhancing liquid lenses. He also explains how each procedure needs to be done in the correct order. As I learned from the graduate student when conducting the experiments, one step out of order means you need to start from scratch.

I agree with Zeidabadi's (2012) point of view. We are both trying to figure out how to enhance the process of electrowetting on dielectric (EWOD). He feels that this enhancement of liquid lenses can be used for micro cameras, displays, and e-books. We have the same hypothesis of contact angle saturation which is time-dependent. I am using a software called COMSOL Multiphysics and all the simulation are under time-dependent. A water droplet can change the saturation in different time scales. Basically, his article is a tutorial for our experiment. Everything he did is like a template for our experiment except we introduce a new material in this process, which is called Graphene. This article gives me further insight on what to expect during the research process.

Dr. Cheng (2012) and Zeidabadi (2012) both had the same approach to enhance liquid lenses. They both are using the concept of electrowetting. They both are measuring the contact angle of a water droplet on a dielectric material. They are both concerned with how this will change the focal length of the lens. Dr. Cheng (2012) and

Zeidabadi (2012) both have the same objective to come up with new applications for liquid lenses and their procedures are closely related. They both took their time to make sure each step was correct. They both knew that the experiment was very tedious, but they both got the results they wanted.

The only difference between the two authors is the material they use. Dr. Cheng (2012) introduced graphene, which Zeidabadi (2012) did not used. Dr. Cheng (2012) wanted to do something that had not been done before. This made his research more unique. Zeidabadi (2012) used a type of metal and a glass. Both articles helped our research figure out which approach was necessary. Ultimately, graphene is what we used. This is important because I never did this type of research before, so, it is a guide for how to do the research.

In the blog article by Smith (2013), he describes software that I will utilize during my research. This software provides a wide range of interfaces to simulate different models of geometric shapes using microfluids (Smith, 2013). He discussed how COMSOL was used in the article "Graphene quilts for thermal management of high-power GaN transistors". He went into more depth on how to use COMSOL to simulate a model of graphene. This is beneficial for our research because we are using graphene and I need to figure out how to show the contact angle change on the liquid lenses. This article shows a few ways to model graphene and test my hypothesis before the actual experiment is completed. This particular article discussed another author's point of view on how to use the software. Since the content is not familiar to me, formulating in an opinion is difficult. I will use Smith's work as a guide, with the help of my mentor, to simulate graphene on this software.

In the article by Cerro (2010), he describes the relationship with Young and the Young-Laplace Equation. Young-Laplace Equation focuses on capillarity, the curvature of the interface and the specific interfacial free energy of the interface, are related to the pressure jump between the inside and outside of a liquid droplet. While Tomas Young focuses on wetting, the contact angle for a three-phase region. He then derives the Young-Laplace Equation for surface curvature. For my research, we are using Young-Laplace Equation. I personally have never used this equation before, so this article will help me with background information and give me understanding of the equation.

All in all, the literature review of this research helped guide me down the right path of electrowetting while using graphene and COMSOL, and that gave me a good idea on where to start with my research. All the authors provided a similar point of view on electrowetting and liquid lenses. I found that the gap was how to use COMSOL to simulate water droplets on a EWOD using graphene. Many of the articles touch some aspects, but not the exact idea that we have. This is the area where I will concentrate my research for the summer.

#### METHODS

The importance of this research is to simulate three different case studies to see how the contact angle would change. This can be measured through the liquid which meets a solid surface. Cerro's presentation (2010) gave me more of an insight on the equation. He explained how this equation can be used. One thing I notice about this article is that he discusses the boundary condition at a time. This is valuable information for my research since we are trying to change the contact angle, to do this we need a boundary condition. Here, he explained how to use the equation to solve for a boundary condition. So, his presentation will help us on the mathematical side of our experiment.

The Young-Laplace Equation is used to solve for the contact angle. The principle of the Young-Laplace Equation is the capillarity, the difference in pressure between two liquids that does not mix. When you think of two liquids that do not mix, you think that their density is different. However, in this research the density of the two liquids are the same. The particles in the fluid are moving at different velocities, so it won't mix. Also, the two fluids' resistance (viscosity) and the surface tension are important because you do not want the liquids to mix. Next, the focus is on what would change the contact angle. Wetting is the process that would help change the contact angle.

Figure 2 shows an example of a water droplet in contact with a solid surface. If you have a contact angle on a solid surface and applied voltage, the contact angle would change.

on a solid

surface



The following is the equation derived from Young-Laplace Equation that will solve for the contact angle,  $\theta$ :  $\sigma_{SV} - \sigma_{SL} = \sigma_{VL} \cos \theta$ 

In finding the contact angle, I need to know the solid surface tension, which allows the surface liquid to resist external force. The solid surface consists of a thin dielectric layer (Electrowetting on Dielectric) and the voltage is applied to this conducting layer. With this information the contact angle expression would be rewritten as:

$$\sigma_{SL} - \frac{\varepsilon V^2}{2d_f} + \sigma_{VL} \cos \theta = \sigma_{SV} \rightarrow \cos \theta = \cos \theta_0 + \frac{\varepsilon V^2}{2\sigma_{VI} d_f}$$

Where  $\varepsilon$  is the permittivity of the dielectric, V is the potential difference applied, and d<sub>f</sub> is the dielectric thickness (COMSOL, 2014). This was valuable information that will help me with the simulation.

In this research, there are two parts. There is a simulation and the live experiment. After these are done, the results are compared to see if our hypothesis is right. I will be focusing on the simulation part. My hypothesis is that the experiment will match the results of the simulation.

For the simulation part, I am using a software called COMSOL Multiphysics. COMSOL is a software that I am using on Windows, which simulates for various physics and engineering application (Griesmer, 2013). For the purpose of this research, the application is liquid lens. I am using this software to simulate the change in the contact angle on liquid lens. This software will help guide us to enhance liquid lenses.

To use COMSOL I need to know the space dimension. COMSOL has six different space dimensions from 0D to 3D. After I pick the space dimension, I need to know what physics you want to simulate for. COMSOL can be used for a variety of physics. After I pick the physics, I need to know what study you will look into. This set up is crucial for this specific research because it has to match with the setup of the live experiment.

#### MATERIALS

Graphene, COMSOL Multiphysics software, and equipment for setup the live experiment.

#### PROCEDURE

My research is approximately seven weeks.

• Week 1 & Week 2: I downloaded and learned how to use COMSOL by doing tutorials from the COMSOL manual and a tutorial on Electrowetting Lens.

- Week 3 & Week 4: I conducted Case 1 study, water droplet on an electrode with voltage applied on the contact angle.
- Week 5 & Week 6: I conducted Case 2 study, water droplet with voltage applied on both sides.
- Week 7: I conducted Case 3 study, the exact same device as in the live experiment.

**Case 1.** I used the same tutorial on Electrowetting Lens to conduct Case 1 Study. I setup COMSOL as the following:

- 1. 2D axisymmetric
- 2. Fluid Flow > Multiphase Flow > Two-Phase Flow, Moving Mesh > Laminar Two-Phase Flow, Moving Mesh (tpfmm)
- 3. Preset Studies > Time Dependent

After the initial setup, I have to define the model geometry. Since Case 1 Study is a water droplet with voltage applied to the contact angle, I drew a half circle with a Bezier Polygon quadratic line splitting the half circle into two sections. This will show the two different liquids that do not mix.

Next, before COMSOL can simulate anything, you need to define parameters for the material properties and for the constants. This is where Young-Laplace Equation is applied. According to Table 1, these are the values that you need to input in COMSOL to apply voltage for the water droplet.

Next, I defined the contact angle according to the rewritten expression of the contact angle. According to Table 2, this equation was derived from Young-Laplace Equation in order to fine the contact angle. Then, you need to set up the material properties. According to Table 3, these are the values for the liquid at the top and according to Table 4, these are the values for the liquid at the bottom.

Then, the physics need to be defined and the boundary conditions must be applied for both the moving mesh and the fluid flow. The boundary condition is the contact angle that I am testing to see if it changed.



#### Figure 4: Boundary Condition

Next, we defined the contact angle settings at the wall fluid interface and set the Navier slip boundary condition. This would let the contact angle to move. This is where the electrowetting effect occurs. Next we set up the mesh deformation boundary conditions for upper and lower boundaries and applied a pressure point constraint. The mesh will help the solution to become more accurate.

The next step in the process is to define an integration operator that can be used to compute the height of the center of the meniscus above the base of the lens. Then, we add a parametric sweep on the viscosity of the insulating liquid. Then we solve the problem over an appropriate time interval. This is where the Time Dependent interphase comes in. The time Dependent study is used when field variables change over time ("COMSOL 4.4 for Windows").

**Case 2.** I used the same tutorial on Electrowetting Lens to conduct Case 2 Study. The setup for COMSOL is the same. The only thing that was different was the geometry setup. Since Case 2 Study is a water droplet with voltage applied to both sides, I drew a rectangle with a Bezier Polygon quadratic line splitting the rectangle into two sections so there is a distinction between the two liquids. The parameters were the same as the tutorial. The boundary condition was different. I had to choose both sides for the voltage.



#### Figure 7: Boundary Condition for Case 2

**Case 3:** I used the same tutorial on Electrowetting Lens to conduct Case 3 Study. The setup for COMSOL is the same. The only thing that was different was the geometry setup. Since Case 3 Study has to be exactly the same as the device in the live experiment, I can design the device in 2D or 3D.

#### RESULTS

**Case 1 Outcomes.** After the setup for Case 1 Study, the following is a representation of how the contact angle would move if the voltage is applied: **Figure 10:** 

**Case 2 Outcomes.** After the setup for Case 2 Study, the following is a representation of how the contact angle would move if the voltage is applied:

#### Figure 11:



My expectations were to compare my results with the live experiments. However, I did not meet my expectations. There were limitations along the way. For Case 3 Study, I realize that it is not certain if COMSOL can simulate a design like the live experiment. The live experiment uses different physics that is not available in COMSOL. I did not look to see if there was another software to use to help me simulate Case 3 Study. Also, my team took a year to grow graphene and make a liquid lens to test for the live experiment. However, the device was successful for only one time and it needs to work more than one time. So, I have nothing to compare to.

#### DISCUSSION

**Case 1.** According to Figure 10, it shows the fluid velocity magnitude and direction after the voltage is switched. The contact angle changed from the original position. In order for the liquid lens to have optimum performance, the oscillation of the meniscus should be damped out as rapidly as possible and the system should be critically damped, bringing the system back to its equilibrium position as soon as possible. (COMSOL, 2014).

#### Figure 12: 1D Plot



As you can see, to the far right corner of the figure, the system would be close to being critically damped; the three fluid's viscosity almost a line with one another. So, this shows that it is possible for the contact angle to change if voltage is applied at the water droplet contact point.

**Case 2.** According to Figure 11, even though I applied voltage on both sides, the boundary condition on the left changed.

#### Figure 13: 1D Plot

As you can see, the sytem is critically damped. So, the contact angle would change if voltage is applied to both

sides.



**Case 3.** I was suppose to simulate the same device as in the live experiment. However, it is uncertain if COMSOL have the study or the physics that relates to the live experiment. So, I can not compare my results. Also, the live experiment is not complete in order to compare results. However, the work I did closely matched with my team's pre-experimental work. So, I was in the right direction.

For this research, I started working with COMSOL software first. I should have figure out what my team was doing first and see if it matches with COMSOL in the beginning. Then, I wouldn't have to go through the whole process and realize I can not finish the research because of a setback.

#### CONCLUSION

Overall, the purpose of this study was to come up with new devices and applications. However, it has already taken my team a year to work on the liquid lens device and my partner just test the device and it only work one time. The reason for the device did not work could be either there were no connection or the graphene experienced some cracks. So, the completion of this part would take a longer time. However, there is still hope that the device could work since it worked one time.

The basis of this research was to make new devices and applications because the liquid lens are used in many small devices. I hope that it could be used for laptop webcams. As many cell phones makers try to come up with new devices to make their phones more functional and fashionable for everyday life. My team aimed to accomplish something that is new, makes things easier to use, and is technologically advanced.

I would recommend that my team keeps trying to fix the device and to see what needs to be changed for it to work all the time. For my part of the research, there should be a way to figure out the connection between the contact angle and the voltage. Also, there should be a factor of where to apply voltage; does it have to be restricted?

#### REFERENCES

- Cerro, R. L. (2010, April 16). Contact Angles: Laplace Young Equation and Dupre-Young Relationship. University of Alabama
- Cheng, M. M. (2012). Electrowetting on dielectric experiments using graphene. Nanotechnology, 375501.
- Cheng, M. M. (2012, November 12). Graphene-Based Flexible Bioelectronics. Wayne State University.
- COMSOL (2014). Electrowetting Lens Tutorial. Retrieved June 10, 2014, from http://www.comsol.com/model/download/177475/models.mfl.electrowetting\_lens.pdf
- COMSOL 4.4 for Windows. (2014, April 16). COMSOL Multiphysics®. Retrieved July 20, 2014, from http://www.comsol.com/product-download
- Griesmer, A. (2013, March 6). What is COMSOL Multiphysics? | COMSOL Blog. COMSOL Blog What is COMSOL Multiphysics Comments. Retrieved July 15, 2014, from http://www.comsol.com/blogs/what-is-comsol-multiphysics/

Petersen, J., & Foster, N. (2014, June 7). What is a Liquid Lens?. *WiseGeek*. Retrieved June 13, 2014, from http://www.wisegeek.com/what-is-a-liquid-lens.htm.

Smith, D. (2013, March 27). COMSOL Blog. *The Graphene Revolution: Part 2*. Retrieved June 15, 2014, from http://www.comsol.com/blogs/the-graphene-revolution-part-2/

Zeidabadi, M. 2D Liquid Lens Based on EWOD. Retrieved June 9, 2014, from http://upcommons.upc.edu/pfc/bitstream/2099.1/16052/4/2D\_Liquid\_Lens\_Based\_on\_EEWO.pdf

#### TABLES

Case 1 Study: Water Droplet with Voltage Applied to Contact Angle

Table 1

#### Parameters

Name	Expression	Description
thetaO	110[deg]	Zero voltage contact angle
gamma	0.05[N/m]	Surface tension
muoil	8e-3[Pa*s]	Insulating fluid viscosity
epsr	2.65	Relative dielectric thickness
d_f	3[um]	Dielectric thickness
Vapp	120[V]	Applied voltage

*Note:* COMSOL (2014). The only aspect that is different from the table I used for Case 1 and the actual table in the tutorial, thetaO is 110 degrees instead of 140 degrees. The contact angle is smaller than the contact angle in the tutorial. For the other case scenarios, I used the same Parameter Table in the tutorial.

#### Table 2:

#### Contact angle Expression

Name	Expression	Description
theta	acos(cos(thetaO)+Vapp^2*epsr*epsilon0_const/(2*gamma*d_f))	Contact angle

Note: COMSOL (2014).

## Table 3:

### Material 1 (Liquid 1) Property

Property	Name	Value
Density	rho	1000
Dynamic viscosity	Mu	muoil

Note: COMSOL (2014)

Table 4:

Material 2 (Liquid 2) Property

Property	Name	Value
Density	rho	1000
Dynamic viscosity	Mu	1.5e-3

Note: COMSOL (2014)

Table 5:

Viscosity

Parameter names	Parameter value list
muoil	10e-3 30e-3 50e-3

Note: COMSOL (2014)