McNair Program Staff

Director
Patricia A. Quinn, Ph.D.

Research Coordinator
Monty Kozbial Ernst, Ph.D.

Program Assistant
Pamela L. Golden, M.A.

McNair Program
Old Library 2134
University of Wisconsin-Eau Claire
105 Garfield Avenue
PO Box 4004
Eau Claire, WI 54702-4004
quinnpa@uwec.edu
http://www.uwec.edu/mcnair/

The Ronald E. McNair Postbaccalaureate Achievement Program
is a TRIO Program,
funded by the U.S. Department of Education.

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McNair Scholars’ Faculty Mentors

- Kim W. Pierson, Ph.D., Department of Physics and Astronomy
- Paul J. Thomas, Ph.D., Department of Physics and Astronomy
- Gregory J. Madden, Ph.D., Department of Psychology
- Garry L. Running, Ph.D., Dept. of Geography and Anthropology
- Robert J. Barth, Jr., Ph.D., Dept. of Geography and Anthropology
- Joel F. Pace, Ph.D., Department of English
- Michael E. Christopherson, M.F.A., Department of Art and Design
- Steven F. Terwilliger, M.F.A., Department of Art and Design
- Matthew M. Evans, Ph.D., Department of Physics and Astronomy
- Sasha A. Showsh, Ph.D., Department of Biology
- Paula K. Kleintjes, Ph.D., Department of Biology
- April L. Bleske-Rechek, Ph.D., Department of Psychology
From Chancellor Brian Levin-Stankevich

At the beginning of this 2006-07 academic year, I issued to faculty and academic staff a call to action: no matter what your job, what priorities we focus on from year to year or what big goals we set for ourselves, the single question each one of us must ask—each and every day—is, “What can I do to help University of Wisconsin-Eau Claire students succeed? I presented this challenge because what underlies and will continue to set UW-Eau Claire apart among universities is a conscious and deep-seated commitment to our students, a commitment such as the one that drives the staff and faculty mentors of UW-Eau Claire’s McNair Program.

This research journal, named Astra for the “rising stars” whose work it showcases, provides strong evidence that engaging undergraduates in research provides them an especially enriched form of education. The authors of these articles demonstrate what educational psychologist William Perry called “constructed knowledge,” a high level of intellectual development that college students can achieve through integrating knowledge imparted by others with their own personal experiences and reflection. Rarely do students enter college with this thinking style, but those who develop it have inevitably encountered mentors who both present them with challenges to their thinking processes and support them in taking some intellectual risks.

The eleven McNair Scholars featured in the following pages took many kinds of risks. Two physics majors scrutinized the material world at the nano scale, while a third theorized about phenomena and forces at the other end of the solar system. Two biology majors contemplated little known balances—one focusing on the replication of cellular information, and the other on the competition between two species for the precious commodity of wild lupine. Two psychology majors revisioned some human vices—one compulsive gambling and the other jealousy. A geography major predicted and then found settlement sites of precontact Native Americans in Eau Claire county, while two art and design majors brought original, exquisite and provocative works into existence. Finally an English major took seriously a genre most dismiss as “kid’s stuff,” and found in the pages of Superman a bold criticism of the presidential election of 2000.

The McNair Scholars published here have already or will shortly move on to the rigors of graduate work at distinguished institutions throughout the country. They can do this all the more confidently and effectively because as undergraduates they experienced faculty and academic staff members who put student success where it belongs—at the center of the equation. As I take great pride in these eleven UW-Eau Claire students, I also celebrate their mentors whose positive influence and sustained efforts brought their protégés to an especially rich culmination of the undergraduate journey.

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From McNair Program Director
Patricia Quinn

In her article on decorative metal boxes (see pp. 58-64) McNair Scholar Jane-Marie Woodhouse Ovanin explores constructions of this familiar geometric form. She comments on the reason for boxes' enduring artistic potency—namely, the mystery and temptation, as old as Pandora’s tale, of what lies inside. On a larger scale, Pandora’s curiosity suggests that of natural scientists in their attempt to understand the mechanisms of the material world. The Pandora τοπος prefigures social scientists’ inquiries on the drivers of human behavior, and it also echoes humanists’ discourses on the contours of human experience highlighted by culture.

Boxes, one could argue, constitute a regular theme in the McNair Program: no “survivor” of IDIS 381 will forget Schroedinger’s, and many of our behavioral psychology Scholars inherit the legacy of Skinner’s. The research designs McNair Scholars create and explore in depth with their Mentors result from thinking outside the box. James Adams’ Conceptual Blockbusting (from the initial McNair Seminar), along with many activities of the Program, aim to train and reinforce this intellectual talent. Those boxy transects so many of our environmentalist Scholars employ for data collection demonstrate one rather unaesthetic but undeniably useful aspect of the form. One always outspoken English Scholar often likened literary analysis to shadowboxing. Two hundred ninety answer boxes present the options of the Verbal and Quantitative sections of the Graduate Record Exam. And this McNair Director herself admits that in extolling the benefits of graduate school and the doctorate she often—and enthusiastically—mounted the soapbox . . . .

But enough. McNair not only invites promising undergraduates to look inside the mysterious containers of their respective disciplines, but the Program also engages them in better understanding their own interiors—in all those puzzling quantum dimensions. When Oliver Wendell Holmes remarked, “What lies behind us and what lies before us are tiny matters compared to what lies within us,” he spoke like a true Pandoran. For McNair Mentors and Program staff the great reward of our work lies with assisting and observing Scholars as their talent begins to bear mature fruit—to not only see what lies within the box, but through the imposition of our own consciousness—read this as guidance—to lend that talent vigor and ever more polished form.
Journal Disclaimer

While the McNair Program staff has made every effort to assure a high degree of accuracy, rigor, and quality in the content of this journal, the interpretations and conclusions reached in each paper are those of the authors alone and not of the McNair Program. Any errors of omission are strictly the responsibility of each author.
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Fabrication of Copper Integrated 
Circuit Interconnects

by 
Rachel E. Anderson and Dr. Kim W. Pierson, 
Department of Physics and Astronomy

Abstract
This project involves developing a process of fabricating copper interconnect wires in high aspect ratio trenches. Located on a silicon wafer, these trenches when filled with copper create microwires. Following rigorous cleaning, a silicone substrate is placed in a DC-Triode system (designed by Pierson), in which a barrier layer of tantalum is deposited to ensure the adhesion of the copper to the substrate. The copper is then deposited in a Bell Jar vacuum system, where not only is copper sputtered onto the substrate, but by employing dual argon arcs the system “resputters,” that is, it bombards the film with ions that shift and “resputter” the copper ions to enhance the formation of a crystalline structure necessary for the efficient flow of electricity. Referencing this system, Pierson and Anderson sought the “perfect recipe” to fill these micro trenches with the copper structure: they sought optimal levels for the substrate bombarding flux, the target ion flux, the throw distance, as well as the argon pressure and background vacuum pressure. Both the SEM (Scanning Electron Microscope) and the TEM (Transmission Electron Microscope) were used to analyze samples, allowing for observation and analysis of the different layers and crystalline structures.

Inspiration for Research
Twenty-first century technology requires smaller, faster, and lighter electronic devices. The semiconductor industry leads this quest by creating ever more powerful CPU and memory chips that use increasingly complex schemes involving multilayer structures made up of multiple levels of metal wiring. This project assists this development by researching a method of fabricating copper microwire interconnects on silicon wafers, employing a Bell Jar Vacuum System and a resputtering technique.

Background
Contemporary circuits are made by filling microscopic trenches with metal to create the wires. Both the choice of metal and the shape of the trench affect the efficiency of these circuits. One can increase circuit speed by replacing aluminum with copper because the latter’s electromagnetic properties make it more efficient—specifically, it has almost a third of the resistance, a lower processing temperature, and a greater resistance.
to electromigration.

To minimize resistance, the cross section area of the microwires must remain as large as possible. However, increasing the density of components on a circuit requires a narrow width for the wires. Narrow and deep trenches fulfill these two requirements. The resulting trenches have a high aspect ratio: the ratio of depth to width, in our case, is 3μm to 1μm. The difficulty of filling such high aspect ratio trenches with copper to create the miowire interconnects engendered our present research.

The Bell Jar deposition system, employing its dual argon plasma arcs, accomplishes two tasks—sputtering the copper atoms onto the silicon substrate with the use of the bottom arc, and resputtering via utilization of the top arc. Sputtering pulls positively charged atoms from the bottom plasma arc to the negatively biased copper, where it “sputters” off a negative copper ion. The copper atoms are then pulled towards the negative silicon substrate where they form a thin film. Resputtering is the process in which the negatively charged silicon substrate pulls positive argon ions from the top plasma to bombard into the already sputtered copper atoms, causing them to shift and settle into better crystalline structures.

Objectives

The ultimate goal of this research is to optimize a process that may be used in industry, to efficiently fill high aspect ratio trenches in silicon wafers with copper. We aim to determine if the Bell Jar Vacuum Sputtering System and resputtering fulfill this goal.

Method

To efficiently fill up the trench space, we sought a process parameter recipe that optimized eight factors: target bombardment energy, target ion flux, throw distance, substrate bombarding energy, substrate bombarding flux, substrate temperature, argon working pressure, and background vacuum pressure. While the flexibility of our unique system is one of its appeals, this multi-dimensional variable space presents us with several challenges, as each one must be kept in a delicate balance.

Experimental Procedure

To prepare the sample, we placed it trench-side down in acetone, and then in the ultrasound for 2 minutes. Then we placed it in methanol for another 2 minutes in the ultrasound, and last in distilled water for another 2 minutes in the ultrasound. The sample was then placed in the UHV chamber of the DC-Triode deposition system to bake at 200°C for 10 minutes. We then presputtered the tantalum (Ta) target at 10 watts for 2 minutes at a pressure of 4.1×10⁻⁵Torr. After the temperature fell below 100°C, we deposited a Ta liner in the trenches, and sustained a pressure of 4.1×10⁻³Torr, at a power of 10 watts, for 5 minutes. We then transferred the substrate to the Bell Jar Vacuum system, which we pumped down overnight. After the base pressure reached below 5×10⁻⁷Torr, we started baking the sample at 50°C, then began the liquid nitrogen flow and turned on the flange heater. We reduced the sample temperature to about 10°C. We sputtered clean the
copper (Cu) target with the sample shield closed for 2 minutes at a target voltage of 640eV and target current 2mA. Next we deposited (sputtered) for a minimum of 10 minutes at the chosen target voltage and target current for that experiment. After a pre-chosen time, we began resputtering at the chosen substrate voltage and current. Deposition continued for 40 minutes at which point we turned off the system and released the vacuum pressure. We then removed the sample from the deposition system, glued a glass sheet to the trench surface with M-bond adhesive, next used a diamond saw to cut the sample to a desired size, and polished starting with a 30 µm diamond disc, polishing it down to a 0.05 µm Al₂O₃ disc. Finally, we analyzed the result using the Scanning Electron Microscope (SEM).

Results

Results from the Bell Jar Vacuum system compare to research on collimated sputtering. This is shown in SEM pictures in Figure 1 and Figure 2:

**Sample B05**

\[ V_{\text{target}} = 575 \text{ eV} \quad V_{\text{substrate}} = 0 \text{ eV} \]
\[ I_{\text{target}} = 12 \text{ mA} \quad I_{\text{substrate}} = 0 \text{ mA} \]

Pressure = $3.6\times10^{-3}$ Torr

Time = 20 minutes

**Figure 1.** SEM picture of sample B05 after 10 minutes of deposition.

**Sample B05**

\[ V_{\text{target}} = 575 \text{ eV} \quad V_{\text{substrate}} = 0 \text{ eV} \]
\[ I_{\text{target}} = 12 \text{ mA} \quad I_{\text{substrate}} = 0 \text{ mA} \]

Pressure = $3.6\times10^{-3}$ Torr

Time = 40 minutes

**Figure 2.** SEM result of sample B05 after 40 minutes of deposition.

The top of the film was torn away in the preparation process; thus, we were not able to tell how well the deposition system was able to keep the trench open. However, the pictures showed that our results resembled that of collimated sputtering as most of the deposited film lay at the bottom of the trench and not on the sides.

Collimated sputtering is a method in which the paths of the sputtered ions are straightened on their way to the substrate by sending them through a collimator. While the collimator will let pass any atoms coming in normal to the surface, others will either
bond to the collimator walls, or be forced into a more normal path. The result is that the atoms sputter into the substrate closer to 90°, allowing for better trench fill. There are, however, negative effects of a collimator: these include a lower deposition rate (as many of the molecules will bond to the collimator instead of heading into the substrate), more complicated steps, and more system components. In addition, the collimator requires frequent cleaning off of the sputtered copper atoms to impede the further decrease of the deposition rate. Our system, on the other hand, shows the positive results without the mess of a collimator; our trenches stay open, and we have less deposition on the sides of the trenches.

Figure 3 and Figure 4 show the results of respattering. Sample B09 was respattered with an energy of only 40eV, and from this photo, we concluded that this was insufficient. From the dimples on the seams where the top meets the bottom, from the flat lower surface, as well as from the poor crystalline structure, it appears as if the sample was not even resputtered. Clearly, a higher energy needs to be used. Unfortunately, the top film also peeled away on this sample, so we could not determine whether or not this resputtering energy would be sufficient to keep the trench open.

![Sample B09 SEM](image)

**Sample B09**

- $V_{\text{target}} = 645 \text{ eV}$
- $I_{\text{target}} = 4.5 \text{ mA}$
- $V_{\text{substrate}} = 40 \text{ eV}$
- $I_{\text{substrate}} = 1 \text{ mA}$
- Temp = 40° C
- Pressure = $8 \times 10^{-4} \text{ Torr}$
- Time = 40 minutes

**Figure 3.** SEM result of sample B09.

![Sample B07 SEM](image)

**Sample B07**

- $V_{\text{target}} = 645 \text{ eV}$
- $I_{\text{target}} = 4.5 \text{ mA}$
- $V_{\text{substrate}} = 75 \text{ eV}$
- $I_{\text{substrate}} = 2 \text{ mA}$
- Temp = 10° C - 35° C
- Pressure = $8 \times 10^{-4} \text{ Torr}$
- Time = 40 minutes

**Figure 4.** SEM result of sample B07.

In sample B07 the ratio of resputtering to sputtering was too high. We used a substrate energy of 75eV to resputter this example, and as can be seen, this led to a dangerous amount of erosion at the bottom of the trench, where the resputtered atoms almost broke through the lower film and hindered the growth of film at that level. Once again we lost the top film, so we could not assess the success of keeping the trench open.
We did notice some positive results from sample B011, shown in Figure 5. Not only did the trench remain well open, but the film achieved high deposition on the top and bottom of the trench, but little on the sides. In this more promising example it seems that the atoms were sputtering with a high cosine angle distribution. We were able to conserve the top film in B011, making it possible to notice that two layers formed above the silicon substrate. While we did deposit a barrier layer of tantalum, this latter was only deposited for 5 minutes; thus, the thickness of the bottom layer was surprising. Either the tantalum layer was thicker than previously imagined, or a reaction layer was forming.

**Sample B011**

\[
\begin{align*}
V_{\text{target}} &= 1310 \text{ eV} \\
I_{\text{target}} &= 6.2 \text{ mA} \\
V_{\text{substrate}} &= 0 \text{ eV} \\
I_{\text{substrate}} &= 0 \text{ mA} \\
\text{Temp} &= 20^\circ \text{C} \\
\text{Pressure} &= 8 \times 10^{-4} \text{ Torr} \\
\text{Time} &= 10 \text{ minutes}
\end{align*}
\]

*Figure 5.* SEM result of sample B011.

We conducted an EDS analysis, shown in Figure 6. However, all Ta peaks were on top of either Si or Cu peaks, making it difficult to determine the composition of this extra layer.

*Figure 6.* EDS analysis of sample B011.

We did notice some positive results from sample B011: the trench remained well open, but the film had high deposition on the top and bottom of the trench, but little on the sides. This promising result suggests that the atoms were sputtering with a high cosine angle distribution.
Conclusion

Results showed that this experimental project has achieved success in replicating the promising results of collimated sputtering and long throw distance sputtering, with fewer complicated steps, fewer system components, but with a higher deposition rate. Furthermore, while respattering involves some promising features, it needs proper boundaries to prevent damage.

Future plans include the development of a series of experiments focused on the parameter space for respattering. We seek a recipe that resputters the film off of the top and sides without digging into the bottom of the trench, and the enhancement of the SEM preparation process to improve the analysis of our results.

Acknowledgments

I would like to offer my foremost thanks to Dr. Kim Pierson for his dedication as a research advisor. Furthermore, I am grateful to the U. S. Department of Education, Ronald E. McNair Postbaccalaureate Achievement Program for sponsoring my research.

Resources


Forces Affecting the Trajectories of Particles in Saturn’s E-Ring

by

Tiffany J. Black and Dr. Paul J. Thomas,
Department of Physics and Astronomy

Abstract

Composed of small micron-sized blue particles, Saturn’s E-ring spans an area of 3 to 8 Saturnian radii. Its existence cannot be explained by disruption within the Roche limit. Using Enceladus, Saturn’s satellite, as the source of E-ring particles, the researchers plotted trajectories of μm sized particles with various initial speeds and directions using a Maple worksheet that models the various forces acting on these particles. Such forces included the gravity of Enceladus, the gravity of Saturn, Coriolis force, centrifugal force, the gravity of the Sun, and the gravities of Saturn’s other satellites. It was discovered that many of these forces had small but not negligible effects upon the trajectory, and that the gravity of Enceladus accelerates the expansion of the ring.

Introduction

Saturn’s E-ring is one of the mysteries of the solar system. Existing outside the Roche limit, it has been studied in various ways, ranging from spectral analysis to computer simulations modeling its formation. In order to better understand the research that has been done on Saturn’s E-ring, some general information about Saturn, its moon Enceladus, and the composition of the E-ring must be known.

The E-ring is one of the outermost rings of Saturn, the sixth planet from the sun. The planet was originally discovered by Galileo in 1610, but its ring structure was not discovered until 1659 by Christiaan Huygens. The planet is one of the gas giants of the solar system and is known for its large ring system. In the upper levels of its swirling atmosphere, the winds can reach speeds of 1800 kilometers per hour. It is the second largest planet in the solar system, second only to Jupiter, but has the lowest density in the solar system. Its density is so low that if the planet were ever placed in a gigantic lake of water, it would float. Saturn’s gravity is one of the major governing forces acting on the particles within the E-ring. The planet’s strong magnetic field might also affect the E-ring if the ring particles become charged, for example by collisions (Hamilton, “Saturn”).

In addition to Saturn’s importance for the E-ring, Enceladus, one of the satellites of Saturn, also may play a crucial role. This satellite is considered to be an icy satellite (a satellite composed of H₂O ice) and may be the source of the E-ring particles. The moon is very similar in size to Mimas, another of Saturn’s moons, but Enceladus is much more
highly reflective, reflecting nearly 100 percent of the light that hits it. The moon itself is characterized by a variety of terrains, such as fissures, plains, corrugated terrain and other crustal deformations, areas with many craters, and areas completely clear of craters (Hamilton, “Enceladus”). Some hypothesize that this is due to the moon’s having a liquid core maintained by tidal heating in similar fashion to that of Jupiter’s moon Io (“Saturn (planet)”). Due to the moon’s proximity to Saturn, the planet’s gravitational field has a large affect on the shape of its orbit. Saturn’s other moons, Tethys and Dione, also affect the orbit of Enceladus.

![Saturn's Satellites and Ring Structure](image)

**Figure 1.** Saturn, its rings, and its satellites. *(Image courtesy of NASA.)*

It has been theorized that Enceladus is the fountain supplying the particles that continually rejuvenate Saturn’s E-ring. Due to the ring’s distance from the planet, its existence cannot be explained by using the Roche limit. The Roche limit is a theory which describes how rings can exist within a certain limit due to tidal forces that rip apart satellites within that limit apart. Tidal forces are caused by the inverse square dependence of gravity over distance. Tidal forces exert a much stronger force on the face of the satellite closer to the planet than on the one facing away from the planet. If the satellite is large enough, this difference in the magnitude of the respective forces exerted will be large enough to break the satellite apart. The limit at which this occurs is approximately 2.4 times the planet’s radius.

\[
    r_{lim} < 2.5 \left( \frac{\rho_p}{\rho_m} \right)^{1/3} R_p
\]

**Equation 1.** The Roche limit (“The Roche Limit”).

Smaller objects can exist within the Roche limit because they are held together by forces
besides gravity (atomic and molecular forces.) Within the Saturnian system, moons and other objects range in size from 10 km to 50 km in radii ("Saturn's Rings").

**Figure 2.** Enceladus (taken by Voyager 2). Note the areas with and without craters. *(Image courtesy of NASA.)*

**Figure 3.** The surface of Enceladus (taken by the Cassini Orbiter at a distance of 1,180 km). *(Image courtesy of NASA.)*

The E-ring extends from about 180,000 km (3 Saturnian radii) to 640,000 (8 Saturnian radii) and appears to peak in the vicinity of Enceladus. The particles range in size from 0.7 μm to 1.3 μm, and appear to have a slightly bluish tint, which has led some to hypothesis that the particles are made up mainly of ice. It has also been stated that this tint may be due to the uniform size of the particles forming the ring (Sanders, 1995). Other researchers do not believe the ring is composed of ice at all, but believe it is made up of fine dust particles (Hamilton, 1994; Ip, 2001; Esposito, 2002).

The particles of the E-ring move in highly elliptical paths which cross the paths of other Saturnian satellites and collide with the embedded satellites at large velocities. The paths of the particles in the E-ring are influenced by the charged nature of the particles, usually negative, and their interaction with the dipolar magnetic field of the planet.

When modeling the E-ring, various researchers have adopted different stances regarding the most important forces and conditions. All include the effects of the gravity of the planet, but otherwise the choice of focus diverges. Electromagnetic forces, solar radiation pressure, plasma drag, Lorentz force, planetary oblateness, and initial conditions all constitute forces and aspects included in various studies (Hamilton and Burns, 1994; Thiessenhusen et al., 1999; Hamilton, 1993; Hamilton, 1994; Dikarev and Krivov, 2004).

The authors of one of the most widely cited papers, "The Origin of Saturn’s E-ring: Self-Sustained, Naturally," claim that collisions of E-ring particles with embedded satellites cause the optical depth of the ring to be sustained. This model identifies Enceladus as the particle source. The particles are assumed to be in elliptical orbits that precess in space due to Saturn's equatorial bulge. Besides the gravity of the planet, the model takes into account strong nongravitational forces, such as electromagnetic force and plasma drag. Other forces included in the model were the Lorentz force (which arises due to the
fact that the charged particles are moving through a rotating magnetic field) and radiation pressure. The model examines the interaction and cancellation between the precession caused by oblateness and the recession due to the Lorentz force (Hamilton and Burns, 1994).

In an earlier study by Hamilton, the perturbation theory was applied to micron sized particles in the E-ring and the radiation pressure used in the model included planetary obliqueness. The study also included rederivation of formulas for the Lorentz force that arises from the dipolar and quadripolar components of the planet's magnetosphere (Hamilton, 1993).

In “Influence of the Initial Motion of Ejecta and of Plasma Drag on the Shape of Saturn’s E Ring,” the researchers examined the roles which the initial motion of the particles as they left Enceladus and the plasma drag play in the trajectories of the particles in the E-ring. They took existing models of the E-ring and added in these two factors. Upon doing this, they concluded that the initial motion of particles ejected from Enceladus causes a vertical ring extension in good accordance with the observed ring height profile, and that plasma drag and an ejection of dust preferentially in the direction of Enceladus’ motion lead to a radially asymmetric density profile of the ring, also in qualitative agreement with the observations (Thiessenhusen et al, 2003).

Although most researchers agree that Enceladus is the source of the E-ring, some, such as Jurac and Johnson, have hypothesized that an optically unseen object near Enceladus is the source of the water particles and some of the OH particles in the E-ring. They found that grain lifetimes in the E-ring are short, only about 50 years for a 1 μm sized particle. In formulating their model, they suggested that the collisions between icy fragments, possibly a disrupted satellite, are responsible for the replenishing of the particles in the E-ring (Jurac and Johnson, 1999).

Methodology

In order to reconfirm that Enceladus is the source of the particles of the E-Ring and to study the roles of factors that affect those particles, a program was made in MAPLE. (MAPLE is a program that allows symbolic and numerical programming in a mathematical language.) First, the numerical constants, such as the mass of Enceladus and Saturn, were included. The initial launch velocity was set at 2000 m/s, which is approximately ten times the escape velocity of Enceladus (200 m/s). The initial velocity was set to be much greater than the escape speed to ensure that the particles took a large enough orbit that the gravity of Saturn would not cause them to impact Saturn within a relatively short amount of time. A launch angle, alpha, was set for each angle. Alpha equal to zero radially points toward Saturn.

During the first trials only Saturn’s gravity, Enceladus’ gravity, Coriolis force, and centrifugal force were included. The center of the Saturn/Enceladus system was located at (0,0) on our coordinate system. Since the system is set up in an inertial reference frame rotating at the same ω as Enceladus, Enceladus always appears at the same location on the graph, (0, R_{Enceladus}).
As our program was set up to take parametric equations, each force had to be broken down into its x and y components.

\[ a_{sx} = -\frac{Gm_{\text{Saturn}}x}{(x^2 + y^2)^{3/2}} \]
\[ a_{sy} = -\frac{Gm_{\text{Saturn}}y}{(x^2 + y^2)^{3/2}} \]

**Eqs. 2 and 3.** Accelerations due to Saturn's gravity (x component and y component).

\[ a_{ex} = -\frac{Gm_{\text{Enceladus}}x}{(x^2 + (y - R_{\text{Enceladus}})^2)^{3/2}} \]
\[ a_{ey} = -\frac{Gm_{\text{Enceladus}}(y - R_{\text{Enceladus}})}{(x^2 + (y - R_{\text{Enceladus}})^2)^{3/2}} \]

**Eqs 4 and 5.** Accelerations due to Enceladus' gravity (x component and y component).

\[ a_{\text{centrifugal x}} = \omega^2 x \]
\[ a_{\text{centrifugal y}} = \omega^2 y \]

**Eqs. 6 and 7.** Accelerations due to centrifugal force (x component and y component).

\[ a_{\text{coriolis x}} = 2v_y \omega \]
\[ a_{\text{coriolis y}} = -2v_x \omega \]

**Eqs. 8 and 9.** Accelerations due to Coriolis force (x component and y component).

A loop was set up so that the position, velocity, and acceleration were recalculated after each timestep and then those numbers were used in the calculation of the next set of data points. A timestep of one hour was used as it is sufficiently small in comparison with the rotation period of Enceladus. The number of timesteps used in each trial was variable, ranging from 200 to 10,000 timesteps. After completion of the loop, the position data was
plotted. Other data plotted included radius vs. time and acceleration vs. time.

Following basic program functioning, other forces were added to the model. These included the gravities due to other saturnian satellites: Mimas, Titan, Tethys, and Dione. Mimas, Tethys, and Dione were included due to their location within the E-ring, and Titan was included due to its large mass. The gravity of the Sun was also added. In order to study the effects of each force, two trials were simultaneously run through the loop: one including the force to be studied and the other lacking it. The particle trajectories were then plotted and the effects were noted. Each set of trials was run four times: once from $\alpha = 0^\circ$, once from $\alpha = 90^\circ$, once from $\alpha = 180^\circ$, and once from $\alpha = 270^\circ$.

Enceladus' role was also studied in the same manner and used to examine the effects of the included forces. The set of trials was repeated numerous times from different launch angles including, but not limited to $\alpha = 0^\circ$, $90^\circ$, $180^\circ$, and $270^\circ$.

Results

Through numerical comparisons, the magnitudes of the accelerations due to the Sun, Enceladus, Saturn, centrifugal force, Coriolis force, Poynting-Robinson force, and plasma drag were compared. The magnitudes of many of the accelerations were not large, but were not negligible (See Table 1).

<table>
<thead>
<tr>
<th>Position (r,e)</th>
<th>Velocity (u,v,w) in m/s</th>
<th>$\mathbf{A}_{\text{gravity - Saturn}}$</th>
<th>$\mathbf{A}_{\text{gravity - Enceladus}}$</th>
<th>$\mathbf{A}_{\text{Coriolis}}$</th>
<th>$\mathbf{A}_{\text{Poynting-Robinson}}$</th>
<th>$\mathbf{A}_{\text{Plasma Drag}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(r,0)</td>
<td>0.12626.20</td>
<td>0.6609567143</td>
<td>3.82805610</td>
<td>6.32636908</td>
<td>0.67044996</td>
<td>1.34001681</td>
</tr>
<tr>
<td>(+r,0)</td>
<td>0.12626.20</td>
<td>0.6609567143</td>
<td>3.82695868</td>
<td>6.32636908</td>
<td>0.67044996</td>
<td>1.34001681</td>
</tr>
<tr>
<td>(0,-r)</td>
<td>0.12626.20</td>
<td>0.6609567143</td>
<td>3.82805610</td>
<td>6.32636908</td>
<td>0.67044996</td>
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<td>(0,0)</td>
<td>0.12626.20</td>
<td>0.6609567143</td>
<td>3.82805610</td>
<td>6.32636908</td>
<td>0.67044996</td>
<td>1.34001681</td>
</tr>
</tbody>
</table>

Table 1. Comparison of values of the accelerations at given positions and velocities.

The accelerations due to Saturn, the Coriolis force, and the centrifugal force were the largest in magnitude. Surprisingly, the magnitude of the acceleration due to the Sun

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was a thousand times larger than the magnitude of the acceleration due to the gravity of Enceladus. The acceleration due to the Sun, however, varied only slightly as the particle moved in its orbit. Though the acceleration caused by Enceladus was small, it was not negligible and had a notable effect upon the particle trajectories. The accelerations due to the Poynting-Robinson force and plasma drag were on the order of $10^{-20}$ smaller than the acceleration due to Enceladus. Because these magnitudes were so small and especially since they were tiny in comparison to the other forces being examined, the accelerations due to the Poynting-Robinson force and plasma drag do not appear among the following ring models.

**Figure 5.** Trajectories of particles with Titan's gravity (red) and without (blue): 3000 hours from $\alpha = 0^\circ$

**Figure 6.** Trajectories with Enceladus (on the left) and without Enceladus (on the right) 5000 hours from $\alpha = 0^\circ$

The study of the accelerations due to the gravities of Dione, Titan, Mimas, and Tethys revealed that these forces need to be included. Plots of the trajectories of particles with and without the accelerations due to the gravity of the individual satellites reveal that the satellites help expand the size of the ring. Lacking the accelerations due to the satellites' gravities, the ring is smaller in size.

The gravity of the satellite Enceladus, in general, appears to greatly amplify the ring. Without Enceladus' gravity, the ring would only span the area between three and
four Saturnian radii instead of the observed three to eight radii. This effect, though true in general, is not true from launch angles between α = 28° and α = 140°, where the acceleration due to Enceladus' gravity expands the ring size, but constrains it within a smaller bound than trials from other launch angles. The difference in behavior may be due to the fact that these particles are launched from the leading face of Enceladus.

Figure 7. Trajectories of particles with Enceladus (red) and without (blue) for 5000 timesteps from approximately α = 28°

Figure 8. Trajectory of one particle launched from α = 0° for 3000 timesteps using the model with all non-negligible forces included. (Red is with accelerations due to Dione, Tethys, Mimas, and Titan; blue is without.)

Figure 9. Eight particle trajectories using the model with all non-negligible forces. Each color represents a different particle's trajectory. The yellow and violet trajectories represent particles which impact Saturn. (The parts of these trajectories that leave the main area of the ring should be ignored since the particles would have already impacted Saturn.)

Following identification of all non-negligible forces into one worksheet, a trial was run to confirm the model's accuracy. This required results which were within the observed location of the ring: 3 to 8 Saturnian radii. Multiple particles were launched at
once in an effort to create a model E-ring. The final trial resulted in a plot of 8 particle trajectories and used the model which included all non-negligible forces. Each of the different particles had a different launch angle: $\alpha = 0^\circ, 45^\circ, 90^\circ, 135^\circ, 180^\circ, 225^\circ, 270^\circ$, and $315^\circ$. The resulting model matched the location and size of the observed E-ring.

Conclusion

The forces which were deemed non-negligible for the scale of our model included the gravities of Saturn, Enceladus, Mimas, Titan, Tethys, Dione, and the Sun. Other forces included were those that arise due to the inertial reference frame. Many of these forces were small in magnitude. The study of Enceladus’ role demonstrated that its gravity plays a key role in the spreading of the E-ring.

Appendix

| Distance from the Sun (Semimajor axis of orbit) | 1,428,725,400 km (9.5370732 AU) |
| Mean Equatorial Radius | 60,268 km (0.449 of Earth’s radius) |
| Volume (Earth = 1) | 765 |
| Mass | 564.5 ± 101 g |
| Mass (Earth = 1) | 9.52E+01 |
| Density | 0.70 g/cm$^3$ |
| Gravity | 896 cm/s$^2$ |
| Equatorial surface gravity (m/s$^2$) | 9.06 |
| Escape Velocity (at equator) | 35.49 km/s |
| Sidereal Rotation Period (Earth Days) | 0.44909 days |
| Rotational period (seconds) | 1023 |
| Sidereal Orbit Period | 29.43498 sidereal years |
| Orbital period (years) | 29.458 |
| Mean Orbital Velocity | 9.732 km/s |
| Orbit Eccentricity | 0.030496 |
| Tilt of axis (degrees) | 25.33 |
| Orbit Inclination to Ecliptic | 2.48446° |
| Inclination of Equator to Orbit | 26.7° |
| Atmospheric Temperature (at level with pressure = 1 bar) | 134 K |
| Mean cloud temperature | -123°C |
| Atmospheric composition | Hydrogen 97%, Helium 3% |
| Magnitude (V mag) | 0.67 |

Table 2. Saturn Data (“Saturn Fact Sheet”)

| Date of discovery | 1789 |
| Mass (kg) | 8.484E+19 |
| Mass (Earth = 1) | 1.4256E-05 |
| Equatorial radius (km) | 250 |
| Equatorial radius (Earth = 1) | 3.919E-02 |
| Mean density (g/m$^3$) | 1.24 |
| Mean distance from Saturn (km) | 238,020 |
| Rotational period (days) | 1.376218 |
| Orbital period (days) | 1.376218 |
| Mean orbital velocity (km/sec) | 12.64 |
| Orbital eccentricity | 0.0545 |
| Orbital inclination (degrees) | 0.02 |
| Escape velocity (km/sec) | 0.212 |
| Visual geometric albedo | 0.09 |
| Mean surface temperature | -241°C |

Table 3. Enceladus Data. (Hamilton. “Enceladus”)
Bibliography


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Toward an Animal Model of Gambling

by
Dr. Gregory J. Madden\textsuperscript{a}, Eric E. Ewan\textsuperscript{b},
and Dr. Carla H. Lagorio\textsuperscript{b}

Abstract
Laboratory investigations of gambling are frequently criticized as lacking ecological validity because the stakes wagered by human subjects are not real or no real monetary losses are experienced. The authors suggest that these problems may be partially addressed by studying gambling in laboratory animals. Toward this end, data are summarized which demonstrate that pigeons will work substantially harder and prefer to work under gambling-like schedules of reinforcement in which the number of responses per win is unpredictable. These findings are consistent with a delay discounting model of gambling. A second prediction of this delay discounting model is that unpredictable win amounts should not make gambling wins more reinforcing. Thus, in Experiment 1 four pigeons worked for predictable or unpredictable amounts of food under a wide range of fixed-ratio schedules of reinforcement. Consistent with the discounting model, no significant difference in response output was observed across the fixed- and random-amount conditions. In Experiment 2, four new pigeons were constantly allowed to choose between earning fixed or random amounts of food. Consistent with the discounting model and the results of Experiment 1, preference did not significantly deviate from chance across a wide range of fixed-ratio values. Beyond supporting the delay discounting model of gambling, the findings support the utility of studying animal behavior as an ecologically valid first-approximation model of human gambling.

Introduction
Laboratory studies of the cognitive and behavioral determinants of pathological gambling have used a variety of methods, most of which employ human subjects either making choices between hypothetical risky outcomes (e.g., Nygren, 1998; Tversky & Kahneman, 1981) or engaging in simulated gambling tasks (e.g., Breen & Zuckerman, 1999) that sometimes include gains and losses of money provided by the experimenter (e.g., Dixon & Schreiber, 2004). While these studies have revealed a number of important processes that appear to underlie pathological gambling (e.g., cognitive biases and stimu-
lus events that may prolong gambling episodes), they each suffer from their own oft-described shortcomings (for a review, see Orford, Sproston, Erens, White & Mitchell, 2003). For example, several studies have revealed that risky decision making may differ when real or hypothetical outcomes are used (e.g., Feather, 1959; Irwin, McClelland, & Schulze, 1992; Lafferty & Higbee, 1974; Levin, Chapman, & Johnson, 1988; Slovic, 1969). Likewise, a number of researchers (e.g., Breslin, Sobell, Cappell, & Vakili, 1999) have questioned the “ecological validity” of simulated gambling procedures.

Of course, practical limitations are driving these procedural shortcomings. For example, in the United States, laws prevent researchers from studying gambling when subjects use their own money to play (Dixon & Schreiber, 2004), gambling establishments routinely bar researchers from conducting experimental or observational studies (although see Lyons & Ghezzi, 1995), and arranging real monetary consequences for choices made over extended periods of time is most often impractical. The study of pathological gambling would benefit from methods that allow assessments of steady-state patterns of risk-taking where the consequences of each decision are real.

Animal subjects research can accommodate each of these requests and the results of classical- and operant-conditioning experiments with animal subjects are often invoked when discussing the determinants of gambling in humans. For example, gambling is ubiquitously described in psychology textbooks (e.g., Gray, 1999; Weiten, 2001) and scholarly literature reviews (e.g., Orford et al., 2003; Petry & Roll, 2001) as behavior maintained by a variable-ratio schedule of reinforcement. While this account is technically incorrect, gambling activities do obtain rewarding outcomes (e.g., monetary wins; presentation of stimuli, like three aces, which are predictive of forthcoming wins; etc.) according to a similar, random-ratio (RR) schedule. Under a RR schedule each response has a constant probability of obtaining a reward and, much like people at slot machines, animals working under RR schedules respond at high, constant rates (e.g., Sidley & Schoenfeld, 1964).

Beyond the ability to arrange ecologically valid and important consequences, the study of gambling in animal subjects opens the possibility of conducting meticulously controlled experiments in which pharmacological variables are manipulated and neurological measures taken. Consider the recent report by Dodd et al. (2005) that Parkinson's patients prescribed pramipexole (a dopamine agonist with greater affinity for D3 receptors) often reported the development of pathological gambling which was attenuated when the patients discontinued use of the medication. Conducting a randomized clinical trial investigating the effects of pramipexole on human gambling would be ethically questionable and procedurally difficult given concerns about the ecological validity of human laboratory gambling. However, if an animal analogue of human gambling were developed, a range of acute and chronic pramipexole (and other D3 agonists) doses could be tested.

Development of an adequate animal analogue of human gambling has the additional potential to explore neural activity throughout gambling episodes. For example, in vivo microdialysis techniques are now available which allow for real-time measures of
neurotransmitters such as dopamine and 5-hydroxytryptamine (5-HT) in brain regions such as the prefrontal cortex which are believed to be important in decision making (e.g., Winstanley et al., 2006). These studies are currently impossible with human subjects.

Despite the potential gains, surprisingly little research has been designed explicitly to study gambling in nonhumans. One notable exception is the work of Kendall (1987, 1989) who demonstrated that pigeons preferred a risky source of food despite the fact that this preference resulted in a decrease in overall food intake. In Kendall’s studies “gambling” had a 10% probability of producing a win (several low-cost food rewards) and a 90% probability of producing a lengthy timeout (during which all lights in the chamber were extinguished and no food rewards were delivered). If Kendall’s pigeons chose not to gamble they would be assured of obtaining a food reward after completing 30 key-peck responses. Despite these odds, the pigeons chose to gamble on most trials even when their daily food intake declined.

To our knowledge, these findings have had very little impact in the gambling literature. For example, neither study was cited in the comprehensive literature review provided by Petry (2005) and a PsycINFO search (May 9, 2006) revealed that these studies had been cited a combined total of two times. Perhaps not surprisingly, to our knowledge no follow up studies have been conducted on “gambling” in nonhumans.

Two studies recently conducted with pigeons in our behavioral economics laboratory may have important implications for the understanding of pathological gambling. While these studies have been published elsewhere, in those papers we did not discuss why our findings are relevant to the study of gambling, so here we present a brief review of the methods and findings along with a brief discussion of these implications.

In the first study (Madden, Dake, Mauel, & Rowe, 2005) four pigeons worked for food in a closed economy under two different schedules of reinforcement. In closed economy experiments, extended session durations (22.5 hrs in this case) allow for the study of consumption and labor supplied (spending) when no supplemental sources of income are available (i.e., no post-session feedings) and the only constraint on consumption is price (where price is operationalized as the number of discrete responses per earned food pellet). Closed economy procedures are particularly useful models of behavior occurring outside the laboratory because, unlike most operant conditioning experiments, factors such as fatigue, satiation, and income are allowed to vary in the manner in which they vary outside of the laboratory (e.g., subjects are food deprived only if they earn an insufficient amount of food during the extended-duration experimental session).

In one condition of the Madden et al. (2005) study, pigeons pecked an illuminated disk (hereafter referred to as a response key) to earn three 45 mg food pellets according to a RR schedule. Unlike human gamblers, the pigeons did not make a monetary wager but instead expended their labor directly in pursuit of the appetitive rewards. Prior research (e.g., DeGrandpre & Bickel, 1995) has demonstrated that “spending” one’s labor directly on the acquisition of addictive substances produces results comparable to spending money obtained through that labor to purchase the same commodity. Like human gamblers, every response that our pigeons made had a constant probability of pro-
ducing a win. Thus, sometimes the subject obtained food after the first peck at the response key, while in other instances many responses were required before food was obtained. The number of responses required each time was, from anyone’s perspective, unpredictable. This condition was designed to mirror the contingencies operating at a slot machine.

In a second condition, the same pigeons worked for the same food rewards, but this time they were available according to a fixed-ratio (FR) schedule. Under this arrangement, the number of responses per food pellet was constant from reward to reward. FR schedules have long been used to model fixed wage rates in the behavioral economics lab (e.g., DeGrandpre & Bickel, 1995; Rachlin, 1982). Thus, this condition was designed to represent the common conditions in which humans work where there is a constant, predictable relation between the amount of work provided and the amount of compensation provided by an employer.

To insure that any differences across these two conditions were due to the unpredictable nature of the RR schedule, rather than differences in the price of food, the average number of pecks per pellet was held constant across the RR and FR conditions. Each condition continued for at least 10 days and until the total number of key pecks per day met a quantitative stability criterion. Each pigeon completed each condition and if a difference was observed across conditions, a reversal was conducted to insure that the difference was replicable within subjects. These procedures were repeated at six different prices ranging from 1 to 256 responses per food pellet.

Figure 1 shows the average number of responses emitted per day in the RR and FR conditions. The averages represent steady-state responding taken from the last six sessions at each price. Three aspects of these data are noteworthy. First, as the price of food pellets increased, RR schedules maintained considerably (and significantly) more responding than did the FR schedules. Indeed at the highest price, two of the four pigeons were unable to maintain a healthy weight under the FR schedule but the next day when the schedule was switched to RR (and this was signaled by changing the color of the response key) both birds emitted at least 97,000 responses, earned substantially more food, and recovered their weight in the process. These data illustrate that the schedule of reinforcement arranged in gambling contexts (RR) not only maintains uninterrupted patterns of responding (as has been often noted in the gambling literature), but maintains substantially more behavior than a fixed-wage payment arrangement (FR).

The second noteworthy aspect of these data is that as the price of food increased, the pigeons’ income declined. The fact that motivation-enhancing effects of the gambling-like RR schedules emerged as a function of income decrements appears to mirror the observation that low income humans tend to spend a larger proportion of their income on gambling than higher income individuals (e.g., Miers, 1996) and that pathological gambling tends to be over-represented in low income brackets (National Research Council, 1999).

Third, the results of the Madden et al. (2005) study were predicted by a mathematical equation that describes how rewards lose their efficacy as they are increasingly
delayed. This is noteworthy because we believe that this equation may have important implications for understanding human gambling. The equation was developed by a number of researchers studying the behavior of rats, pigeons, and humans choosing between immediate and delayed food rewards (e.g., Chung & Herrnstein, 1967; Green, Fray, & Myerson, 1994; Mazur, 1987). In the ensuing years, the equation has been demonstrated to more accurately describe both human and animal behavior than a comparable equation used for decades in the economics literature (for a review see Green & Myerson, 2004). Briefly, the delay discounting equation holds that as the delay \( D \) to the delivery of a reward increases, the value \( V \) of the reward declines according to a hyperbolic-like discounting function:

\[
V = \frac{A}{(1 + kD)^s}
\]

where \( A \) is the amount of the reward and \( k \) is a free parameter that quantifies the rate at which the reward is discounted as delays increase (\( k \) is often referred to as a measure of impulsivity) and \( s \) is a scaling factor. Figure 2 illustrates a hyperbola-like discounting function using \( k \) and \( s \) values commonly observed in animal subjects (humans discount delayed rewards at a much lower rate, smaller \( k \) value, but the same equation describes human behavior as well as it does animal behavior; Green & Myerson, 2004). As illustrated in Figure 2, the discounting function is deeply bowed, reflecting the observation that rewards rapidly lose their value in the range of brief delays and then slowly lose further value at longer delays.

**Figure 1 (above).** Average number of responses emitted per day during the stable sessions in the fixed-ratio and random-ratio conditions at each response requirement in Madden et al. (2005, Experiment 1). Error bars represent one standard deviation in each direction.

**Figure 2 (above right).** Hyperbolic discounting functions demonstrating discounted values of fixed-ratio (solid data points) and random-ratio (open data points) rewards. Upper panel shows values at low prices; lower panel shows values at high prices. In both, the dashed line represents the average value of the random-ratio rewards.
Figure 2 illustrates why daily work output by pigeons in the Madden et al. (2005) experiment was undifferentiated across the FR and RR conditions when food was available at low prices (i.e., when pigeons made 1 or 4 responses per pellet in Figure 1). At these prices the amount of time required to complete the FR response requirement (D in Equation 1) was very brief, and because the number of pecks required was the same each time, D was approximately the same each time. Given this, the solid data point in the upper panel of Figure 2 shows the discounted value of the FR rewards. The open points correspond to the values of RR rewards. Here the work requirements, and corresponding delays to food delivery (D) varied between rewards, but because the average price of RR and FR rewards were the same, the range of delays to RR rewards was constrained to the linearly decelerating portion of the discounting function. As such, the average value of the RR rewards (shown as the horizontal dashed line) was approximately the same as the value of the FR rewards and thus, consistent with the findings in Figure 1, RR rewards did not generate more daily responding than the FR rewards in the low range of prices.

The lower panel of Figure 2 illustrates why Equation 1 predicts that RR rewards should motivate more behavior than FR rewards in the upper range of prices. As before, the solid data point shows the discounted value of FR rewards, and the open points show the values of five RR rewards representative of the range of times required to complete the unpredictable response requirement of the RR schedule. Unlike the upper panel of Figure 2, this range now spans a larger portion of the discounting function given that a wide range of response requirements could be experienced in the higher price range under the RR schedule (recall that like a slot machine, every response has a constant probability of obtaining a reward on a RR schedule). Calculating the average discounted value of the RR rewards (dashed line) yields a value that more than doubles that of the FR reward. Hence Equation 1 predicts, consistent with the findings shown in Figure 1, that the RR schedule should maintain more responding than the FR in the upper range of prices.

Given that numerous experiments have demonstrated that humans discount delayed outcomes according to a hyperbola-like function (see Green & Myerson, 2004 for a review), there is reason to predict that at high prices humans would be more motivated by RR than FR rewards; though to our knowledge no systematic empirical investigation of this has yet been conducted. When applied to gambling, Equation 1 suggests that humans may be expected to view gambling wins as more attractive than working predictable amounts to earn a comparable reward when these rewards may be obtained at only high work-to-reward ratios. This situation may best describe the alternatives facing low-education and low-income individuals. The observation that both of these populations are more likely to be classified as problem or pathological gamblers (e.g., Shaffer, Hall, & Vander Bilt, 1999; Volberg, 1994) would seem to offer at least indirect support for this analysis.

This analysis describes decision making but the Madden et al. (2005) experiment did not allow pigeons to choose between the FR and RR work requirements. Thus, Madden and Hartman (in press) examined four pigeons’ choices between these predictable and unpredictable work requirements across a range of food prices. As suggested by the
analysis in Figure 2, Equation 1 predicted subjects would be indifferent between the two schedules of reinforcement at low prices, but that preference for the RR alternative would emerge as prices were increased. Figure 3 shows that this prediction was confirmed and the small error bars corresponding to a full standard deviation in both directions indicates that this shift characterized the choices of every subject.

![Graph showing average percentage of choice of the random-ratio schedule during the stable sessions at each response requirement in the Madden and Hartman (in press) experiment. Error bars represent one standard deviation in each direction.](image)

Figure 3. Average percentage of choices of the random-ratio schedule during the stable sessions at each response requirement in the Madden and Hartman (in press) experiment. Error bars represent one standard deviation in each direction.

Clearly these findings represent only a first approximation of an animal model of human gambling. Human gambling contains considerably more variables which may play an important role in maintaining gambling activities and each must be subject to an experimental analysis. Of course, a number of these variables lie outside the purview of that which may be studied with animal subjects (e.g., self-generated rules and subsequent rule-following), but many variables can be studied with further animal experiments. For example, one shortcoming of the studies from our lab that have been summarized so far is that the amount of the reward was always the same (3 food pellets) and this is not characteristic of most human gambling contexts. For example, a wide range of payouts are possible when playing a slot machine, playing poker, or scratching a lottery ticket. Custer and Milt (1985) hypothesized that experiencing a large win amount, particularly early in one’s experience, may increase the probability of subsequent gambling. Unfortunately, very little empirical work has been done on this phenomenon and what does exist suffers from a number of the procedural shortcomings discussed above (for a review, see Weatherly, Sauter, & King, 2004).

Others have hypothesized that unpredictable reward amounts may play a role in maintaining gambling above what would be maintained by predictable fixed-amount jackpots. For example, citing studies conducted with animals foraging for food under laboratory conditions (e.g., Caraco, 1980), Petry (2005) suggested that humans may be more likely to gamble when variable reward amounts are won. As noted by Petry, the fact that “jackpot only” slot machines (with their predictable reward amounts) are unpopular in Las Vegas casinos (Wildman, 1997) appears to support this hypothesis generated from risk-sensitive foraging theory (McNamara & Houston, 1992). Unfortunately, a compre-
hensive review of the animal foraging literature suggests that preference for variable reward amounts is rarely observed, but when it is the effect appears to be critically linked to income (Kacelnik & Bateson, 1996). That is, as an animal's income is insufficient to maintain its health, the animal should prefer the risky, unpredictable reward amount as this gamble may pay off and keep it alive. To our knowledge, however, no experiments have examined whether variable reward amounts are more likely to maintain behavior than equivalent fixed-amount rewards in a closed economy. As noted above, closed economies more closely resemble the contexts in which humans gamble because the subject's behavior is continuously observed in lengthy sessions, and the animal's behavior directly affects its income. Therefore, in our first experiment the price of food rewards (i.e., the number of key pecks per reward) was held constant across two conditions in which either fixed-amount (3 pellets) or variable-amount (average of 3 pellets) rewards were available, and behavior was examined in a closed economy.

Contrary to the predictions of risk-sensitive foraging theory, Equation 1 holds that unpredictable win amounts will not increase the probability of behavior above levels maintained by predictable reward amounts, all else being equal. This prediction is made because amount appears in the numerator of Equation 1, where it does not affect the shape of the discounting function; it simply determines the y-intercept (at \(A\)). Thus, Experiment 1 was conducted to test these divergent predictions by examining the daily labor supplied by pigeons working under fixed- or variable-amount schedules of food reinforcement in a closed economy. All else was held constant, including the FR schedule under which all rewards were obtained and the average price of rewards across conditions. If unpredictable win amounts enhance the gambler's motivation to make wagers, then daily responding in the variable-amount condition should exceed that emitted in the fixed-amount condition.

**Experiment 1**

**Method**

*Subjects.* Subjects were four adult male White Carneau pigeons with previous experience responding under a variety of schedules of reinforcement. Subjects were housed for 23 hr per day in the experimental chambers described below. Between sessions, subjects were housed in large exercise chambers that provided sufficient room for them to move their wings freely, fly short distances, and perch. Water was continuously available during and between sessions.

*Apparatus and Materials.* Four Coulborn Instruments operant chambers, each 30 cm long, 24 cm wide, and 29 cm high, were used. Each chamber was inside a separate light and sound attenuating enclosure. A metal dish filled with water was connected on the outside of each chamber and a hole in the right wall allowed the bird to reach the water. One plastic response key was positioned on the response panel 19 cm from the floor and 3 cm from the right wall. This response key could be rear-illuminated with red or green light provided by 28 V lamps. A 28-V houselight was located 7 cm above the response key. A 45-mg food pellet dispenser (Coulbourn Instruments, Allentown, PA) delivered 45 mg
food pellets (Noyes Formula C1, Research Diets Inc, New Brunswick, NJ) into a 7-cm wide by 8-cm high custom-built food trough (these pellets constitute a complete diet). The trough was equipped with a 28-V light and was designed to hold several hundred pellets without spilling them onto the floor. Each chamber was equipped with a white noise speaker and a ventilation fan to mask outside noises. A Med Associates interface system located in an adjacent room controlled the sessions and recorded data.

**Procedure.** Experimental sessions were programmed to begin at the same time each day (11:00 am), seven days a week, and each session lasted for 23 hrs. Throughout the experiment, food reinforcers were obtained by completing FR schedules (i.e., a constant number of responses per reinforcer event). Due to the subjects’ previous experience pecking keys for food in unrelated experiments, no pre-training was required.

Each session began with the presentation of the houselight and the illumination of the response key. When the response requirement was completed by pecking the key, the keylight flashed on and off in 0.5 s pulses for a period of 10 s. During this 10 s period, responses on the key did not count towards completion of the next response requirement. When food was scheduled to be delivered contingent upon key-pecking, 45 mg pellets were delivered, one per second, to the food trough. Accompanying each pellet was a 0.5 s tone from a small speaker (model 273-060A, Radio Shack). After this 10 s period, the keylight was relit and responses on the key counted towards completion of the next response requirement.

Distinct schedule-correlated key colors (red and green) were assigned to the Fixed-Amount (FA) and Variable-Amount (VA) reinforcers at the beginning of the experiment and remained unchanged throughout the experiment (colors were counterbalanced across subjects, see Table 1). Under the FA schedule, completing the response requirement produced three pellets every time. This schedule was designed to model one component of non-gambling wage contexts: predictable payment amounts. Under the VA schedule, the number of pellets delivered was randomly selected without replacement from a negative binomial distribution (0, 0, 0, 0, 1, 1, 1, 2, 2, 3, 4, 5, 6, 7, 9, 10) with a mean of three pellets and a standard deviation of 3.11 (see Ito, Takatsuru, & Saeki, 2000). Thus, like human gamblers, our pigeons expended resources on outcomes that sometimes resulted in either no reward but a stimulus display (flashing keylight), or the same display and a VA reward.

Table 1 shows the sequence of FR schedule values, schedule types (FA or VA), and number of sessions completed until responding had stabilized at each schedule type. Responding was judged stable when at least 20 sessions had been completed, no trends in responding were visually apparent, and the average number of responses emitted in the last three sessions deviated from the mean of the prior three sessions by 5% or less. Two pigeons (79 & 96) did not meet the stability criteria under either schedule type at the highest ratio value because their weights dropped below a healthy sustainable level before the criteria could be met. For these subjects, the average responding in the final six non-stable sessions is reported.

Beginning at FR 3, each subject completed both the FA and VA schedules (the
order of which was counterbalanced across subjects). If the stable daily response output differed significantly between the two schedules (as determined by a Wilcoxon’s matched-pairs, signed ranks test), within-subject reversals were conducted; otherwise, the next FR value in the sequence was arranged. This process was repeated until responding was assessed at five different prices ranging from 1 to 128 responses per pellet in the FA and VA conditions.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Schedule-Correlated Color</th>
<th>Schedule Value</th>
<th>Sequence (# of sessions)</th>
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Table 1. Experiment 1: Sequence of FR schedule values, schedule-correlated key colors (RA = Random Amount; FA = Fixed Amount), schedule types, and number of sessions completed in each condition for each subject.

Throughout the experiment the houselight remained on for the first 5 hour and 43 minutes of the session. For the next 12 hours the houselight was darkened but the keylight remained on and the response-reinforcer contingencies remained unchanged during the dark period. The houselight was re-illuminated for the final 4 hours and 47 minutes of the session.

Results & Discussion

Figure 4 shows the average number of responses emitted per day during the stable sessions at each price (i.e., responses per pellet) in the FA and VA conditions types (error bars indicate one standard deviation in each direction; note the logarithmic coordinates). When reversals were conducted at a particular price, the stable data were combined into a single mean and standard deviation in the figure because no significant differences were detected between any of these conditions (p > .05 in all cases). Across the range of response requirements examined, subjects emitted more responses per day as the price of food increased; a significant effect of price was detected by a one-way ANOVA (F(4,19) =23.33, p < .0001). By contrast, responding was not significantly affected by whether the
three food pellets (FA reward) or an average of three pellets (VA reward) were delivered at each reinforcer event (Wilcoxon’s signed ranks test; $Z = 0.62, p = .54$).

According to risk-sensitive foraging theory, pigeons should be more motivated to respond for the VA than the FA reinforcers as their income declines and they lose weight. Figure 5 shows the average weight (shown as the percentage of pre-experiment free-feeding weight) during the stable sessions at each FR response requirement in the FA and VA reward conditions (error bars indicate one standard deviation in each direction). As required by risk-sensitive foraging theory, Wilcoxon’s signed ranks tests revealed that all subjects lost significant weight (when compared to FR 3) at the two highest prices in both the FA ($Z = 2.52, p = .01$) and VA ($Z = 2.38, p = .02$) conditions. Thus, the conditions required by risk-sensitive foraging theory were satisfied without supporting its predictions.

**Figure 4.** Average number of responses emitted per day during the final sessions in the variable- and fixed-amount conditions at each response requirement. Error bars represent one standard deviation in each direction.

**Figure 5.** Average weight of subjects during the final sessions in the variable- and fixed-amount reward conditions at each response requirement. Error bars represent one standard deviation in each direction.

By contrast, these findings were consistent with the predictions of the hyperbola-like discounting formula (Equation 1). When the present results and the predictions of Equation 1 are applied to gambling activities, they suggest that variable win amounts do not enhance the motivation to play, at least not in pigeons. Although the procedures used in this experiment mirror those that have proven sensitive to the motivation-enhancing effects of unpredictable work requirements (Madden et al., 2005), previous studies (e.g., Hamm & Shettleworth, 1987) have demonstrated that choice is more sensitive to reinforcer amount manipulations than is responding when only one reinforcer type is available at a time. Because humans live in a choice context in which gambling activities may nearly always be sought out or forgone, in Experiment 2 we allowed pigeons to choose between earning food from FA and VA alternatives. If subjects did not prefer the VA reward in Experiment 2, this would offer stronger support for the position that unpredictable reward amounts do not enhance the attractiveness of gambling activities.
Experiment 2

Method

Subjects & Apparatus. Subjects were four adult male White Carneau pigeons with previous experience responding under a variety of schedules of reinforcement. Housing and between session arrangements were the same as Experiment 1. The experimental chambers used in this experiment were the same as those used in Experiment 1 except that a second response key located 3 cm from the left wall and 19 cm from the floor was added.

Procedure. Experimental sessions were programmed to begin at the same time each day (11:00 am), seven days a week, and each session lasted for 23 hrs. Throughout the experiment, FA or VA food reinforcers could be obtained by completing FR schedules on the left response key (hereafter referred to as the response key). At the beginning of each session, the response key was illuminated with either red or green light, each correlated with either the FA or VA reward (see Table 2). Throughout the experiment, subjects could change the reward type (and correlated color) arranged on the response key by making a single response on the right, changeover key. Before the experiment began, subjects were trained to use the changeover key by arranging for food reinforcers following pecks to one response key color, but not the other. When, on 90% of the trials, for three consecutive days, subjects pecked the changeover key before the non-reinforced response key color, the key color assignments were switched and subjects were required to meet the 90% criterion again.

Following changeover key training, sessions began with the illumination of the houselight, the response key, and the changeover key. The color of the response key was randomly determined by the computer. On the first two trials, subjects were required to change the reinforcer type (FA or VA) by pecking the changeover key once (additional pecks had no programmed consequence) and then pecking the response key. These forced-choice trials were designed to force the pigeons to sample the FA and VA reinforcers when their respective colors were present on the response key. They also ensured that subjects remembered the function of the changeover key throughout the experiment. This procedure has been demonstrated to produce choices that are sensitive to differences in schedule contingencies arranged on the response key (e.g., Madden & Hartman, in press). Choices made on forced-choice trials were not counted when calculating choice percentages.

After the forced-choice trials, subjects were free to choose between the FA and VA reinforcers every time. Presentation of these alternatives on the response key strictly alternated between trials such that if no changeover responses were made, the pigeons would obtain equal numbers of FA and VA reinforcers. In each trial, the first peck to the response key turned off the changeover key until the next reinforcer had been delivered. When the FR response requirement was completed by pecking the response key, the response keylight flashed on and off in 0.5 s pulses for 10 s. During this period, responses on the response key were not counted toward completing the next response requirement. When food had been earned, 45 mg pellets were delivered, one per second, to the food.
trough. After this 10 s period, the keylights and houselight were relit and responding was counted towards completing the next response requirement. The within-chamber light-dark schedule was as in Experiment 1.

<table>
<thead>
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<td>Green</td>
<td>Red</td>
<td>12 72 192 300</td>
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Table 2. Experiment 2: Sequence of fixed-ratio (FR) schedule values, schedule-correlated key colors, and number of sessions completed in each condition for each subject.

Table 2 shows the sequence of FR schedule values and number of sessions completed until each pigeon’s choices had stabilized. Choices were judged stable when at least 20 sessions had been completed, no trends were visually apparent, and average percent choice of VA reinforcers in the last three sessions deviated by 5% or less from the mean percentage in the final three sessions. One pigeon’s responding did not meet the stability criteria at the highest price tested (100 pecks per pellet for pigeon 90) because his weight dropped below a healthy sustainable level before the criteria could be met. For this subject, the average responding in the final six non-stable sessions is reported.

Results and Discussion

Figure 6 shows the average percentage of choices of the VA schedule across the range of prices arranged (error bars indicate one standard deviation in each direction). Across these prices, a binomial test revealed that on average, pigeons did not select the VA reinforcers significantly more than the FA reinforcers. ($p > .10$). Further, no linear increasing or decreasing trend was observed across the range of price tested ($F_{(1,2)} = 0.12, p = .76$).

As in Experiment 1, a Wilcoxon’s signed ranks test revealed that subjects’ weights significantly decreased at the highest price (relative to those maintained at the lowest response requirement, FR 12; $Z = 4.29, p < .001$). Given this finding, risk-sensitive foraging theory predicted that preference for the VA reinforcer should be observed at the highest ratio values tested. However, a binomial test indicated that pigeons did not select
this alternative significantly more than 50% of the time during their final six sessions at
the highest price ($p > .10$). When combined with the results of Experiment 1, these
findings offer no support for risk-sensitive foraging theory when examined in a closed
economy. However, the same findings strongly support the predictions of the hyperbola-
like discounting function (Equation 1).

**Figure 6 (above)**. Average percentage of choices of the variable-amount schedule
during the stable sessions at each response requirement. Error bars represent one standard
deviation in each direction.

**Figure 7 (above right)**. Hyperbolic discounting function, using median $k$ values, reported for
pathological gamblers (upper panel) and humans without addictive disorders (lower panel).
In both panels, the dashed line represents the average value of the RR rewards.

**General Discussion**

Two characteristics of virtually every gambling game is unpredictability in how
many wagers must be placed before a win, and variability in the amount that will be won.
Previous studies conducted in our lab revealed that pigeons would work substantially
more for food rewards when the amount of work required per reward (analogous to the
number of wagers placed per win) was unpredictable, but only when the bird’s income
was low (Madden et al., 2005). Similarly, when income was constrained, pigeons preferred
to earn their daily ration of food through this gambling-like alternative rather than mak-
ing a predictable number of responses per food reward.

The results of the present experiments demonstrate that despite predictions to
the contrary by risk-sensitive foraging theory (McNamara & Houston, 1992), when food
intake was constrained pigeons did not work harder, nor did they prefer food rewards of
unpredictable sizes over predictably sized rewards. As noted above, several previous stud-
ies have failed to support this prediction (for a review see Kacelnik & Bateson, 1996) but
the present experiments are the first to demonstrate this across a wide range of food
prices in a closed economy, which more closely resembles natural foraging environments, and the conditions in which human gambling occurs.

To the extent that these findings may be extended to humans, they suggest that unpredictable amounts do not enhance the reinforcing efficacy of gambling wins. This would seem to be at odds with the observation that jackpot only slot machines are less popular than machines that yield unpredictable win amounts. An alternative explanation for this preference in human gamblers is that the variable payment machines undoubtedly pay out more frequently than the jackpot only machines, even if the two pay out the same amount over extended durations. To our knowledge, comparing these payment regimes has not been investigated in animal subjects.

When combined with the findings of the previous two studies conducted in our laboratory, it would appear that unpredictable work requirements, and not unpredictable rewards, are important in the maintenance of gambling behavior (Madden et al. 2005; Madden & Hartman, in press). Together, these four experiments offer strong support for the predictions of Equation 1; the hyperbola-like discounting function. Given this empirical support we will now discuss some further predictions of this equation as they apply to human pathological gambling.

Delay Discounting and Pathological Gambling

As discussed above, Equation 1 describes the manner in which delayed rewards decrease in value for individuals. A number of studies have shown that discounting rate (k in Equation 1) varies between individuals and populations. For example, individuals addicted to a variety of drugs including heroin (e.g., Madden, Petry, Badger, & Bickel, 1997), cocaine (Coffey, Gudleski, Saladin, & Brady, 2003) and nicotine (e.g., Bickel, Odum, & Madden, 1999) discount delayed monetary rewards at a higher rate than matched control participants. More recently, a number of researchers have demonstrated that pathological gamblers also devalue delayed monetary rewards to a greater degree than matched controls (e.g., Alessi & Petry, 2003; Dixon, et al., 2004; Petry, 2001). This means that delayed outcomes are subjectively viewed by the gambler as less important and one can hypothesize a number of ways that this may increase the probability of gambling. For example, pathological gamblers may discount the value of the benefits of gambling abstinence (e.g., improved financial status [Smart & Ferris, 1996], improved family relations [Lorenz & Yaffee, 1986], and avoidance of vocational and criminal complications [Rosenthal & Lorenz, 1992]), choosing instead the relatively small, but immediate benefits of gambling. Likewise, pathological gamblers may discount the delayed aversive events that often accompany their addiction.

While these accounts are intuitively appealing, Equation 1 suggests a second mechanism by which individuals who discount delayed rewards at a high rate may be more susceptible to gambling: as discounting rates increase, the value of rewards arranged according to RR schedules increases. As noted before, gambling wins, whether obtained by playing slots, roulette, or craps, occur randomly following wagers in much the same way that our pigeons obtained food rewards unpredictably following pecks to the response
key. Likewise, conditioned reinforcers (e.g., being dealt three of a kind in poker or two aces in blackjack) are obtained according to RR schedules even in games of skill. Each of these wins, or stimuli signaling an increased probability of a win, plays an important role in maintaining gambling activities. To understand how individual differences in discounting rate affects susceptibility to these reinforcing consequences of gambling requires that we look at a second set of discounting functions.

The format of Figure 7 is the same as that used in Figure 2 but these graphs show how individual differences in discounting rate (i.e., the steepness of the discounting function) affect the relative value of RR and FR rewards. The value of gambling wins should play an important role in determining the frequency of gambling (the more valuable the outcomes of gambling relative to other available rewards, the more frequently we would expect gambling to occur; e.g., Herrnstein, 1970). As before, the amount of time required to obtain FR rewards is approximately the same each time, so the value of these rewards is given by the solid data point in both panels of Figure 7. Gambling wins can occur following any wager and so we have plotted the value of five wins (open data points) obtained following delays spanning much of the discounting function (the value of one of the wins is obscured by the FR reward). The discounting function in the top panel was obtained using the median \( k \) value reported for pathological gamblers by Petry (2001). The overall value of RR rewards has been empirically demonstrated to be the arithmetic mean of all of the obtained, discounted wins (Mazur, 1984). For pathological gamblers, the average of the RR rewards (horizontal dashed line) is nearly double that of the FR reward. Thus, for these individuals, the benefits of gambling far outweigh the benefits of emitting a predictable amount of work (e.g., at a job with predictable pay periods) in order to obtain the same rewards.

By contrast, the lower panel illustrates a lower discounting rate characteristic of humans without addictive disorders (see review by Kirby, 1997). Although the discounting function is still bowed, it is flatter than the pathological gamblers’ discounting curve. Thus, the average value of the RR rewards is only nominally greater than FR rewards. For these individuals we might expect gambling to be an enjoyable activity, but because the values of the two types of rewards are about the same, we would not predict excessive gambling. Further, the slightly greater enjoyment experienced from gambling wins over predictable paychecks is unlikely to be able to overcome the host of aversive outcomes (e.g., loss of money, relationships, etc.) often accompanying excessive gambling. For individuals who discount delayed outcomes at a higher rate, these aversive events face stiffer competition from significantly higher valued gambling rewards.

To conclude, gambling researchers are often forced to accept procedural shortcomings while conducting their experiments. Whether it is the use of hypothetical outcomes, seeding participants with the money they will use to gamble, or prospect choice experiments that may not adequately model the continuous, stable choices made by human gamblers, the procedures of gambling researchers are often criticized for lacking “ecological validity” (e.g., Breslin et. al 1999). Legitimate practical limitations underlie these problems—problems that may be avoided by studying gambling in animal subjects.
As demonstrated in the four experiments presented here, steady-state animal behavior maintained by real rewards can easily be studied over extended periods of time and with a degree of experimental control not available in the human laboratory. While several variables at work in human gambling contexts (e.g., manipulation of stimuli associated with winning) or characteristics of gambling activities (e.g., wagering of money, a conditioned reinforcer to obtain more money) have yet to be studied in the animal laboratory, they are amenable to an experimental analysis, and the outcomes of these studies hold promise for exploring therapeutic interventions or testing of public policy decisions in much the same way that the results of animal experiments have had this impact in the area of substance abuse (e.g., Bickel & DeGrandpre, 1996; Hursh, 1991). The time to develop an animal model of gambling is now.

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Reconstructing the Precontact Chippewa River Valley: Landscape Reconstruction Using GIS and GLO Township Surveys

by

Jennifer L. Freeland,

Department of Geography and Anthropology

Faculty Mentors: Dr. Robert J. Barth, Jr. and Dr. Garry L. Running

Abstract

Previous archaeological research in Eau Claire County suggests that the valleys of smaller streams were intensively used by prehistoric people and formed an important component of their settlement strategy. No systematic study of this aspect of precontact settlement and land use has ever been undertaken, however. It is crucial that such an investigation be conducted now, because increasing residential development along these streams threatens to destroy much of the archaeological database. The goal of this research, the preliminary phase of which is presented here, is to create a GIS-based model of prehistoric settlement patterning along smaller streams in Eau Claire County. The model, created by utilizing ArcGIS software, includes the following data layers: location, age, and cultural affiliation of known sites; hydrology, topography (DEM slope and slope aspect), soils (morphological units by map unit) and surficial geology; original vegetation; and, existing road networks. From the preliminary results, ArcGIS Spatial Analyst will be used to develop a predictive model of site location for testing and refinement. The results of this research will expand our understanding of the prehistory of Eau Claire County and the Chippewa River Valley, as well as enhance subsequent efforts to preserve archaeological sites from encroaching development.

Introduction

The goal of archaeology is to reconstruct past ways of life. In order to do this, archaeologists rely heavily upon inferences from material remains. However, material remains themselves tell us nothing about the behavior of the user; only the artifact’s use can be inferred (Gladfelter). Therefore, the environmental context in which the artifacts were found must be studied as well, as this is an important indicator of the human creators’ and users’ past behaviors. The environment presents opportunities or challenges to which humans must respond. Reconstructing the environment around material remains lends clues as to why those tools were used: “The human element is a component of the environment that cannot be isolated from it...evaluation of prehistoric behavior must also include reconstruction of the physical surroundings” (Gladfelter).

The theoretical basis of predictive models is that certain environmental proxies are often associated with archaeological sites; therefore, where those environmental prox-
ies exist, sites should be found as well. In the literature devoted to predictive models, little information exists regarding why certain environmental elements figure as important indicators of archaeological sites. For example, according to Scott Hamilton, “The issue of why is often not explicitly addressed...a lot of archaeological ‘insight’ is ad hoc and post hoc derived, and frankly, much of it is unstated implicit assumptions about how people used the land in the past.”

Although the large stream valleys, Chippewa and Eau Claire, have been extensively surveyed, the smaller tributary valleys in Eau Claire County have been largely neglected. The scattered research done on the smaller valleys suggests that they constituted an important aspect of settlement pattern. The research objective of this study, to develop a GIS-based model of settlement patterning along small tributary valleys in Eau Claire County, seeks to understand the nature and extent of prehistoric utilization of tributary valleys in Eau Claire County and to develop a predictive site location model.

Methods

For the first phase, we chose six variables to include in the GIS: soils, known sites, historic vegetation, slope characteristics, stream network, and road network. The characteristics included during this phase are scale appropriate. According to Bettis, archaeological remains can be analyzed at three different scales: small, medium and large. A medium scale covers a range in area of hundreds of meters to several square kilometers and a time scale ranging from a few centuries to millennia. The attributes included at this scale include ecotones, soil formations, modification of landforms, changes in vegetation, and changes in stream channel direction and drainage. At medium scale changes in temporal and spatial patterning can be studied in detail, as well as changes in vegetation, animal population, climate, and human adaptation (Bettis). The layers are then broken down into attributes and categories. The soils layer included several attributes: soil map unit, soil class, native vegetation and slope class. Soils serve as important diagnostic tools in archaeology, as material remains are found in soils, and the geomorphologic processes that operate on soils affect the artifacts as well. Soils also hold data that enable a reconstruction of vegetation and habitat (Soils Book). The soils layer was downloaded from the SSURGO Soil Survey and added to the GIS. The known sites layer had four attributes: latitude/longitude, cultural period, type, and artifacts. Table 1 lists the categories included in the known sites layer. The sites were supplied by the Archaeological Sites Inventory, GLO Township surveys completed in the 1850’s (Barnes). Barnes divided vegetation into five categories: prairie, oak openings, oak-pine barrens, pine barrens, and forest. Slope characteristics were derived from a Digital Elevation Model (DEM), downloaded from the Wisconsin Department of Natural Resources (DNR), and added to the GIS. The categories of slope characteristics were slope and slope aspect. Also downloaded were the stream network and road network layers, ones that did not have attributes or categories within them. These layers are similar to those in predictive models with approximately the same environment. The primary phase included a predictive model completed in the prairie uplands of northern Illinois, which employed in the GIS the attributes of historic
vegetation, topographic relief, locations of site, and road network (Handbook).

Figure 1. Map of Eau Claire County. (Roads from DNR; sites from Archaeological Sites Inventory.)

Results

The majority of sites are situated in stream valleys (Figure 1), with the major concentration of sites located along Otter Creek, which was systematically surveyed as both I-94 and US-53 parallel its course (Figure 2).

Figure 2. Map of Eau Claire County. (Roads from DNR; sites from Archaeological Sites Inventory.)

Despite the general purpose and nature of Barnes' map, it shows that the majority of sites are situated along ecotones (Figure 3). Barnes' reconstruction is supported by a pollen analysis from peat bogs throughout the state. These were sampled for pollen and profiles were derived from the samples. There is no direct data for vegetation prior to the Wisconsinian glacial period. However, sufficient data from bogs found in the “Driftless Area” exist to make generalizations about the state’s vegetation to about 12,000 b.p. to the
present. The vegetation changes of Eau Claire County can be summarized as follows: at
about 12,000 b.p. spruce and fir predominated throughout Wisconsin, although in Eau
Claire County, hardwoods and oak were also common. By 3500 b.p. oak had replaced
spruce-fir in Eau Claire County as the dominate tree type. The prairie-forest border at this
time crossed Eau Claire County. South of the border, oak and hardwoods predominated,
while north of the border spruce and fir played this role. The prairie-forest border re-
mained in relatively the same location at 1000-500 b.p. (Curtis, 1959).

Figure 3. Map of Eau Claire County. Vegetation maps are from Barnes (1974).

Today the prairie-forest ecotone crosses Eau Claire County in approximately the
same location as it did on the Barnes map. However, the Barnes vegetation map and the
native vegetation data given in the SSURGO Soil Survey do not agree. SSURGO men-
tions no prairie vegetation at all.

The majority of the sites yielded debitage (Figure 5). Sites with exclusively debitage
are considered to be ones of very temporary occupation. The majority of these sites are
located either in the prairie or along the prairie edges; this suggests that these areas were
used short-term rather than for residence. Their inhabitants had perhaps travelled from
more permanent sites in the main river valleys to take advantage of resources available in
the ecotones.

Other selected attributes did not show a pattern the way these principal six had.
No pattern emerged for site situation on slope or slope aspect. Although soils constitute
important diagnostic tools in archaeology, no pattern arose for site situation on soils.

Conclusions

Our previously held hypothesis—that use of tributary streams constituted an im-
portant component of settlement strategy—was confirmed (Figure 1). The distribution
of known sites is correlated with areas such as highway corridors that were investigated
by Cultural Resource Management surveys (Figure 2).

The first phase of the model provided new information: for example, the known
sites range in age from Paleoindian to Woodland, showing that use of tributary stream valleys occurred during all of the time periods represented in the Chippewa Valley (Table 1). Archaeological work in this portion of the Chippewa River Valley indicates that precontact settlement appears to have been seasonal in nature. Sites along tributary streams represent short-term exploitation of resources outside of the main river valleys. Streams near prairie-forest ecotones are loci of site concentration (Figure 3).

![Map of Wisconsin](image)

**Figure 4.** Map of Wisconsin. Dashed line indicates prairie-forest border.

![Sites with Debitage](image)

**Figure 5.** Map of Eau Claire County. Sites from Archaeological Site Inventory. Streams from DNR. Vegetation from Barnes (1974).

**Future Studies**

The data assembled is insufficient to accurately determine settlement pattern. Of the forty known sites, only six yielded diagnostic remains—not enough to accurately determine settlement pattern. More surveys need to be completed to add sites to the database. In addition, several attributes need to be added to the GIS. To replicate the predictive
model completed in Illinois, our model must include soil drainage and distance to streams. Likewise, a future model will add to the GIS sites vs. soil drainage, sites vs. soil drainage class, and sites vs. distance to a major confluence. Additionally, the discrepancy between the two vegetation sets, SSURGO and Barnes, requires resolution in order to accurately determine historic vegetation.

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<td>Woodland</td>
<td>Pottery and Points</td>
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Table 1. Projectile points and pottery are important diagnostics. The presence of pottery indicates a campsite. Points indicate a possible hunting site. Debitage could be flakes, fragments, or discarded.
References
Superman’s America: Audience, Reception, and President Lex

by

Bobby J. Kuechenmeister, Department of English
Faculty Mentor: Dr. Joel F. Pace

Introduction

Superman debuted as the feature character in DC Comics’ Action Comics in June of 1938, but in that same year he also appeared in daily newspaper comic strips written and drawn by Jerry Siegel and Joe Schuster. These two Jewish-American high school students created Superman in the hope that their character would spur American involvement in World War II. Similar to Jewish refugees from Germany during the Holocaust, Superman was a fleeing immigrant. Despite recent modifications to small details concerning his origins, Superman’s basic story remains the same. Heralding from the doomed planet of Krypton, the infant Kal-El arrives on Earth aboard a rocketship and is raised by Jonathan and Martha Kent, who rename him Clark Kent to protect his alien identity. Once an adult, Clark becomes a journalist working at the Daily Planet newspaper, but he also learns that he possesses superpowers and decides to use them in “fighting a never-ending battle for Truth, Justice, and the American Way” as Superman.

The “American Way” should encompass the concepts of Truth and Justice, but the meaning of these virtues shifts during periods of war or political change. The original politicization of Superman continues into the present and remains relevant to current events. The intertwining of real-time events with comic book fiction presents questions about the nature of truth itself and suggests an ongoing crisis in American culture centered on the subject of truth. Many people consider comic books a type of entertainment that persons often discard after adolescence. Consequently, they ignore the comics industry as a source of political dissent. This oversight also makes comics a genre least subject to censorship. This current research, however, queries Superman’s potential as political commentary, and focuses on a particular example of its use in this vein.

Comic book stories are written months before the publication dates—a problematic situation since Superman incorporates real events, yet the time between their occurrence and reading about them in the comic book can be relatively short. Comic book writers and artists must therefore predict outcomes of a future event as best they can. Nonetheless, since the turn of the present century, writers have used superheroes and the fantasy elements of their worlds to make subtle commentaries about contemporary events. Superman is no exception. One example of this intersection between fantasy and reality is the “Vote Lex 2000” story arc.¹ The “Vote Lex 2000” story relates the events of Lex
Luthor's winning bid for the Presidency of the United States and parallels our own election of that year resulting in the Florida ballot recount.

Superman vs. Lex Luthor

Lex Luthor is Superman’s arch-nemesis and most dangerous opponent because he possesses a high intellect combined with a sociopathic nature. After spending years of his life building Lexcorp, his technology company in Metropolis, Luthor experienced great financial success and subsequent political power, becoming the most powerful citizen in Metropolis. However, his high status within the city was short-lived once Superman made his debut. Superman identified Luthor not as a philanthropist maintaining Metropolis’ best interests, but as a master criminal. This triggered a rivalry between Luthor and the Man of Steel that continues to play out. Aside from the Last Son of Krypton, Luthor also faces opposition locally from newspaper reporters Lois Lane and Clark Kent, who write for the Daily Planet. Lane once uncovered Luthor’s criminal misdeeds and Luthor retaliated by setting off critically placed explosives throughout Metropolis, destroying the city, and thus punishing not only the Daily Planet and its reporters but also all of the citizens of Metropolis. Thanks to the efforts of Superman and other superheroes, the city was rebuilt, but thereafter many shared Superman’s feelings toward Luthor.

The classic Superman-Lex Luthor rivalry is redefined during “Vote Lex 2000” as Luthor makes his bid for Presidency of the United States, but Luthor’s ultimate goal—defeating the Last Son of Krypton—remains the same. Therefore, the plan itself is not what makes this story arc unique and historically relevant; instead, the story stands apart from other previous Superman adventures by how it is executed. Luthor depends neither on kryptonite nor on other supervillains to overcome Superman as he normally might. Instead, Luthor relies on the American voters, combined with his financial and political strength, as a means to propel him into office. However, winning those necessary votes to place him in office as the President of the United States is a difficult task because of his poor rapport with Metropolis citizens and his rivalry with Superman. Luthor warps his negative association with the Man of Steel into a positive for his Tomorrow Party campaign using “Truth, Justice, and the American Way” as a slogan. Luthor so desperately wishes to change his public appearance that he feigns an assassination attempt on himself, and erases his personal records, leaving him a perfectly law-abiding citizen.

Crisis of Truth: Journalism

If one compares events from this Superman story arc with actual ones from Election 2000, a number of meaningful connections are revealed, in particular if one uses a topical approach to the timelines rather than an event-to-event comparison. A crisis of truth becomes visible then and continues into the present. Election 2000 marks the starting point of the most recent crisis of truth, when major news networks miscalled election results in the state of Florida for Al Gore versus George W. Bush. The predictions called into question the integrity of all media as a source of truth, and placed journalism under intensified scrutiny. Millions of Americans rely on some outlet for receiving
news information, whether from television, radio, or internet sources. All people who trust these forms of media believe the reports to be accurate. Our democratic society trusts journalists to tell the truth because a diverse collection of newspapers, news magazines, channels, and websites compete for the public’s undivided attention. These outlets require an audience consisting of readers and viewers who agree with what those sources report, but if journalists perpetuate error, they become the problem, not the solution.

Lois Lane questions her role as a journalist during “Vote Lex 2000” when she says in Superman #163:

I just can’t help but wonder—when does the public need to know the truth? . . . Does the average person have a right to know all that? As reporters are we creating a greater fear than the incident itself? (Loeb 12)

Lane’s concern is important because it highlights the consequences of journalists reporting misinformation. The public’s reaction to untruthful journalism is similar to one friend’s being told a lie by another then learning the truth after the fact. He or she would feel betrayed and afraid thereafter to trust the other person. Likewise, many Americans felt a similar reaction after Election Night 2000. James Poniewozik, a reporter for Time magazine, reported in “TV Makes a Too-Close Call” that the network blunders of awarding Florida to Gore and then Bush “revealed the media’s dual, contradictory roles: national laughingstock and de facto fourth branch of government” (Poniewozik 70). One must wonder, then, how the media maintains its loyal readers and viewers on a regular basis when the public is quick to point out its misreporting when it occurs.

Richard Stengel, another journalist for Time, explained that journalists utilize a concept called “spinning.” According to Stengel, spinning is “selling a version of events that you want others to believe rather than the version that you know to be true” (51). Stengel’s explanation does not relieve journalists from fault when it comes to reporting misinformation because all of them carry the responsibility of checking facts before revealing them; his description suggests, however, that journalists share the blame of misinformation with another source. For example, according to Time, George W. Bush’s records as governor became sealed from public viewing after a DWI charge leaked out. The sealing of records made it difficult for Democrats and journalists alike to learn information about George W. Bush that could have been found offensive by the general public and, consequently, used against Bush on the campaign trail. The “Vote Lex 2000” story arc acknowledges just such a situation. Batman arrives in Metropolis to investigate Luthor as a means of preventing him from winning the election. He explains to Superman and Lois Lane in Superman #164 that “The B13 virus conveniently erased any record of him, criminal or otherwise. Luthor is a model citizen as far as anyone knows.” Batman, possibly the most objective character in the story arc because of his role in the DC Universe as the World’s Greatest Detective and a Metropolis outsider, rarely interacts with Luthor, but he shares with Superman a disdain about the possibility of Luthor’s becoming President. Batman’s findings reveal that Luthor is able to “spin” his own history without opposition; any criminal allegations made by characters like Superman, Clark Kent, or Lois Lane will lack any proof other than their own memories.
Readers are shown Luthor’s version of himself in the rare Superman: Lex 2000 issue. The Superman: Lex 2000 comic book is formatted as an issue of NewsTime, a fictional news magazine that is a cross between Newsweek and Time, featuring a triumphant President-Elect Lex Luthor on its cover. (See below.)


This atypical comic book cover closely resembles an actual news magazine, such as Time’s 2000 “Man of the Year” issue that focused on George W. Bush. The inside cover of NewsTime contains a letter from publisher Collin Thornton3 who writes two flattering paragraphs about Luthor, comparing him to the late President Kennedy, saying “If President Kennedy brought about a new Camelot in America, it is safe to believe that Mr. Luthor will bring about a new Eden,” which is a hypocritical statement since Luthor approached Thornton previously seeking campaign backing. Luthor managed to coerce support from Thornton by telling him first, “The whole point of my Tomorrow Party is to sweep away the old models of cultural and political change—and create a new structure for a new millennium . . . And remember—everyone living in my world is going to be watching movies and television, reading newspapers and magazines—well, the literate ones, at any rate—logging on to the Internet” (DeMatteis 3-4). The duality of Luthor’s statements furthers a crisis of truth by illustrating how politicians phrase something two different ways, leading people to question their agenda, along with their person.

Crisis of Truth: The Public

American society trusts the media to report the truth, but consider how much information (or misinformation) certain news organizations, like Rupert Murdoch’s Fox News, supply during an election year. Thornton is similar to Murdoch, a Republican supporter, as the movie Outfoxed: Rupert Murdoch’s War on Journalism proves. Former Fox
News producer Diana Winthrop stated that “Murdock, who had absolutely adored Ronald Reagan, adored him, had a lot of admiration toward the group of Republicans who controlled Congress on Capitol Hill” (Chapter 1). According to Outfoxed, Murdock reaches a total audience of 4.7 billion people or three-quarters of the world population. Former Fox News employees revealed how Murdock manipulated his organization into a Republican propaganda machine in the movie. Frank O’Donnell, another former Fox News producer, commented on Fox News’ transformation under Murdock when he says

We received an order . . . that we should cut away from our newscast and start carrying a fawning tribute to Ronald Reagan airing at the Republican National Convention . . . We were stunned because until that point, we were allowed to do legitimate news and suddenly, we were ordered from the top, to carry propaganda—carry Republican, right-wing propaganda. (Chapter 1)

Fox News changing its format is not unlike Newsweek suddenly releasing a pro-Luthor edition. The focus on Luthor with nothing about his opponent, the unnamed Texas governor, suggests a lack of objectivity in Thornton’s newsroom like that at Fox News.

Newscasts by Fox News anchors featured constant ad lib commentaries of which Jon Du Pre, former Fox News anchor from the West Coast bureau, said, “Any ad lib that made the Democrats look stupid and made the Republicans look smart would get an ‘atta boy,’ a pat on the back, a wink or a nod” (Chapter 5). Minor cuts against Democrats combined with constant Republican exposure on Fox News influenced voters during the 2000 election. According to Steve Rendall, senior analyst for Fairness and Accuracy in Reporting (FAIR), Fox News’s Special Report featured a five-to-one ratio favoring Republicans from late June to late December of 2003. His conclusion from the survey was that “Brit Hume and Special Report choose their guests based on political considerations rather than news judgment” (Chapter 10). The best example of how Fox News manipulated its audiences and the general public took place when it declared George W. Bush the President on Election Night 2000. John Nichols, author of Dick: The Man Who Is President, explained that Florida’s voting results arrived as a complex set of data and the correct answer was that the race was too close to call. However, Fox News declared Bush as the winner of Florida and within minutes, all other networks followed suit. He said, “There’s no way that they could have crunched the data in that time to come to that conclusion. In fact, quite the opposite” (Chapter 17). The miscalling, as stated before, blurs the line between contemporary America and Superman’s America.

The back matter of Superman: Lex 2000 features quotes from Bruce Campbell, Margot Kidder, Richard Donner, Kevin Smith, plus Jay and Silent Bob—all commenting on Lex Luthor’s presidential bid. All of the commentators further blurred the distinction between Superman’s world and our own by openly choosing Luthor over George W. Bush and Al Gore in Election 2000. A most interesting quote came from Kevin Smith, who said, “Anyone but Bush” which shows support toward Luthor in the fictional context of Superman while stating a preference in Election 2000. These commentators are all actual people who exist in the real world. Therefore, perhaps the responsibility of truth rests with journalism and the public. One problem with such a relationship is that truth may be
manipulated and people make mistakes. Truth, then, is not an absolute concept, as Michel Foucault explains:

Truth is undoubtedly the sort of error that cannot be refuted because it was hardened into an unalterable form in the long baking process of history. Moreover, the very question of truth, the right it appropriates to refute error and oppose itself to appearance, the manner in which it developed ... does this not form a history, the history of an error we call truth? (Foucault 243)

Given that truth is an unstable entity perpetuated by changing times and progressive societies, there is essentially no regulation over any individual from “spinning” his or her own version of themselves.

George W. Bush attempted to improve his overall public image for Time reporter John F. Dickerson. Bush took Dickerson on a tour of his ranch near Waco, Texas, and Dickerson described a side of Bush that most people take for granted when he wrote

Ranger George knows every inch of his acreage. His arm shoots out to point at the different kinds of oaks, the elm and the hackberry .... He stops the truck to show us a rare cottonwood and make sure we can all see the white-tailed deer hiding in the trees .... He catalogs every stream crossing, every canyon and the precise number of cows, bulls and calves that he lets graze on his land. (61)

Dickerson's representation of Bush in the above passage shows him to be a concerned environmentalist who wants to share nature with all people, especially visitors to his ranch, but it is a successful façade that appeals to human compassion and causes us to forget about his sealed records or other misdeeds. Similarly, Luthor performs the same weaving trick in the “Vote Lex 2000” story arc.

Luthor is also shown as an environmentalist from the media’s perspective throughout his campaigning. The first instance is in Superman #162 when Luthor, due to Lexcorp’s experimentation with sound waves, is kidnapped by Aquaman and placed on trial for noise pollution of Atlantis, Aquaman’s sovereign nation. Luthor escapes trial for environmental crime by vowing that Lexcorp would cease its experiments and work with Aquaman to improve the oceans that are shared by Atlantis and the world. The second environmental instance is when Kosnor brainwashes Superman and uses him to attack a dam in Metropolis. Although the situation is remedied by assistance from Superman, Luthor appears on-camera afterwards, claiming to work with Superman closely to repair the damage and prevent other incidents like that one from happening again. Both instances are attempts by Luthor to gain voting support from the population that once rejected him; he associates himself with Superman whenever possible, even using “Truth, Justice, and the American Way” as his campaign slogan. Despite Luthor’s previous attempt at destroying Metropolis, his gambit works and he wins the election.

Conclusion

Election 2000 seriously questioned our society’s understanding of those three concepts Superman represents: Truth, Justice, and the American Way. We may never know the exact number of votes lost or voices unheard due to the Florida ballot scandal,
but the scandal itself identified a failure of democracy, which is cleverly depicted in “Vote Lex 2000” by a seemingly random appearance on Election Night of Bizarro. The latter, Superman’s imperfect clone, is the Man of Steel’s opposite in all respects and functions as a dark mirror image of the Last Son of Krypton: Bizarro’s costume even employs a backwards S-shield. His deplorable use of English grammar contrasts with Clark Kent’s excellent writing skills as a journalist, while the backwards S-shield symbolizes the failure of democracy as Lex Luthor becomes President Luthor.⁶

Notes
1. A “story arc” is a comic industry term for a series of sequential issues telling one story.
2. The B13 virus that upgraded all of Metropolis’ technology is from a previous story arc. Luthor sacrificed his infant daughter to gain control of the powerful upgrade.
3. Collin Thornton is also Lord Satanus, one of Superman’s nemeses, questionably the Biblical Satan.
4. Margot Kidder, co-starring with Christopher Reeve, played Lois Lane in all four of the Superman movies. The back matter imagines the comic book Lois Lane, who is opposed to Luthor’s becoming President, interviewing these people. It is interesting to note, therefore, Kidder’s pro-Luthor stance.
5. Richard Donner directed the first of the four Superman movies starring Christopher Reeve.
6. Special thanks to DC Comics for granting permission to use the cover of “Superman: Lex 2000.”

Works Cited
Continuing the Craft: Contemporary Metal Boxes, Insight from Current Artists, and Work from an Aspiring Metalsmith

by

Jane-Marie Woodside Ovanin,
Department of Art and Design
Faculty Mentor: Professor Michael E. Christopherson

Could the act of lifting a lid off a box increase the sensation or value of seeing its contents? Does the mere possibility of its holding something hidden make it irresistible to look inside? Why do artists choose to create boxes as functional pieces of art? These and other questions surrounding the intrigue of boxes, and my specialization in metalsmithing, led me to formulate an undergraduate project proposal to study metal boxes by interviewing successful contemporary metalsmiths; fabricating small sterling, brass, and pewter boxes; and, shaping a philosophy of boxes. This paper will act as a review of all three endeavors, while also linking them into a unified vision.

My curiosity centers on the box as a specific form, which due to its rigid yet versatile nature became a technical and conceptual learning tool, allowing complete experimentation of design while providing a loose guideline of techniques and materials. The box was a form through which I could artistically explore and develop as a young metalsmithing major at the University of Wisconsin-Eau Claire. My inspiration derived from the success of artists whose boxes were published in Tim McCrieht's *A Metalsmith's Book of Boxes and Lockets*. This book provided a place of departure for my study. I sent a letter and questionnaire to each of the box artists published in McCrieht's book in order to receive information from them on their motivations for becoming artists, reasons for making metal boxes, inspirations for design, and words of advice.

Insight

This straightforward statement by Jane Campbell, a 30-year veteran of metalsmithing from Cambridge Springs, Pennsylvania, exposes a truth about many artists:

"I think artists make things like this (my boxes) because we are dysfunctional and obsessive, and when we can find our niche, we work like dogs and achieve great things. No one needs this work, it is true, but we need to make it. Sometimes people can be uplifted with joy at the viewing of beautiful and clever things, and that is enough. The world need not be all ugliness and fear."

Like Campbell, Marcia Macdonald's motivation is also intrinsic, coming "from a deep place ... that somehow wants to prove something to [her] self." Macdonald is a metalsmith
from Eugene, Oregon who is frequently a guest artist and teacher around the country.

Along with internal drive, external motivators, like selling work to make a living, also inspire metalsmiths. I had the opportunity to visit the studio of a fellow Wisconsinite, Jon Michael Route, who has worked as a full-time metalsmith for over 19 years. He allowed me to visit his home and studio in Frederick, Wisconsin where he makes teapots, vessels, and boxes. He works mainly with pewter, allowing his art to be less expensive, and thus more marketable. The patterns and designs on many of the lids and sides of his work are pressed in by either copper or brass dies on a hydraulic press or by steel stamps on a mechanical press. In addition to his interest in manipulation of surface texture, Route enjoys the overall sculptural aspect of hollowware, and when asked specifically about the appeal of boxes, he said, “People are always interested in looking inside.”

Richard Finney and Myra Milmitsch-Gray posit other appeals for the box. Finney, a sculptor and metalsmith from Winnipeg, Manitoba, explains that, “mostly the reason for the box is that it represents an envelope to hold ‘goodies’ whether these be items, thoughts, or ideas.” Also, Milmitsch-Gray, a metals professor at the State University of New York at New Paltz, articulates that the box “currently functions as a three-dimensional canvas, a carrier of metaphor, but its roots are in utility.”

In order to cover this “three-dimensional canvas,” artists take inspiration from a variety of sources. Joe Muench, an assistant metals professor at Iowa State University in Ames, says that his “work is generally concept driven or inspired by a specific event or individual.” Created while living in Missouri, the piece in McCreight’s text was “inspired by ‘Bruce’ a man who scavenged for scrap metal in the alleys of downtown St. Louis…He supported his family through the metal he found and sold.” Micki Lippe is also stimulated by humanity: “An idea can come from the conversation of people around [her] or an event in [her] life.” Lippe, from Seattle, Washington, has been making jewelry, taking classes, and teaching classes for over 35 years.

Others, like Jane Martin from Washington State, look to “Nature, quilts, fences, color field paintings and buildings [for] inspiration.” In an attempt to make unique jewelry, she chooses not to look at other people’s work for ideas. This has been successful, because “[she] keep[s] making it, and people keep buying it.” One of the few artists who told me she had received ideas from art history was Lorraine Lenskold from Toms River, New Jersey. She is influenced by “…pre Columbus gold of South America, Mayan glyphs, and paintings of Georgia O’ Keeffe.” Therefore, whatever their respective motivations for creating boxes, all the artists with whom I corresponded found the box to be a successful art form in conveying their artistic ideas, influences, or interests.

My Study

The diverse responses received from contemporary metalsmiths provided insight for my own study and fabrication of metal boxes. As I continued to reflect on aspects of the box, I became intent on spending time in the studio and making my own work. I related to a statement written by Tom Muir, head metals professor at Bowling Green State University of Ohio, who explained that fundamentally “people enjoy using their hands
and minds together in a creative way.” Like him, I was also “interested in how artists are inventive and solve problems within sets of parameters,” and I anxiously set out to solve my own obstacles while choosing to work with the general restriction of the box form. With the help of my metals professor and mentor, Michael E. Christopherson, and with funding from the Ronald E. McNair Postbaccalaureate Achievement Program, I set out to “work like a dog” (Campbell).

As I worked 30 to 40 hours a week designing and fabricating my work, I kept a journal throughout the entire summer of 2004 to provide a record of names, books, and techniques that I came across. I agreed with Jan Baum of Towson, Maryland when she affirmed that, “Each piece is a unique problem which had never been solved before.” As I sketched, brainstormed, and began fabricating, my goals were straightforward. First, I wanted to find the solution to four of my own boxes, and second, I wished to create well-crafted art. I found that Tracey Johnson, a fine jewelry maker from Harpswell, Maine, held similar hope, “to produce something that is both visually pleasing…and has intrinsic as well as sentimental value.” I also took to heart the words of metalsmith Tina Chisena from Wheaten, Maryland: “although content is really important, you’ll convey very little with poor technique or sloppy workmanship. So pursue and master all the skills you can, learn them well and that will serve you no matter what sorts of things you decide to make.”

My first project was a brass cylindrical box that I textured by hammering it round over a steel rod. The lid was originally a simple dome, but my mentor and I decided to dap a circle into it. This made the lid asymmetrical and, in my opinion, more interesting. I added additional whimsy by sticking wires of fresh water pearls from the dapped area and soldering a stand-off hinge to the back. However, before this piece was completed, I also began two other projects. Overlapping tasks allowed me to better utilize my time by enabling me to switch activities if I became stuck or aggravated. I worked with sterling silver on my next two rectangular pieces. One displays a rippled lid made from a conforming mold. I set a faceted four millimeter blue topaz stone in the center of the wave, giving a focal point to this delicate, yet striking box. I constructed the other with a thicker gauge and enclosed it with a lost-wax cast top made up of imperfect circles. A delicate hinge allows this box to rest open, displaying the velvet-lined interior.
My last box was made at Penland School of Craft in North Carolina, where I spent my last two weeks of summer research taking a pewtersmithing class from Fred Fenster, metalsmithing professor at University of Wisconsin-Madison. It was a privilege to work with Fenster. His expertise in pewter and his expectations of design and execution facilitated my successful adaptation to working with this new material. Pewter's unique properties, like its lower melting temperature, added some difficulties while fusing and soldering; however, the material's increased malleability was very advantageous while forming, hammering, and planishing. It was my first experience with these techniques, and it was very rewarding to complete my first planished vessel, a bulbous-shaped maple syrup pitcher. During this course I also continued to explore boxes; I made an elegant round box with a flush lift-off lid. The top and side showed a complex and graceful sawed out negative pattern of day lilies. My trip to Penland proved an exceptional way to wrap up my studio work in a demanding and encouraging environment. As I drove the 16 hours back to Wisconsin, I was able to reflect on my work and begin to formulate a hypothesis of why I was compelled to continue the craft of making metal boxes.

Hypothesis

Tara Stephenson from Orchard Park, New York "works with the container format because she is interested in cosmetic compacts." She stated that the history of metalsmithing affected her work, and that "containers have a strong relationship to the history of metalsmithing and/or jewelry." In forming my final hypothesis, I searched to discover such a history, and I found that the box has held significant roles and functions in various historical contexts. In Jewery 7000 Years, the Standard of Ur from 2500 B.C. is recognized as a "hollow rectangular box...its sides are covered with brightly colored mosaics of shell, red limestone and lapis lazuli" (3). This was the earliest reference I found to the box form in relation to jewelry and metalsmithing. Also, hundreds of years ago, metal reliquaries were used in Europe to hold sacred objects. In Herman Schadt’s Goldsmith’s Art 5000 Years of Jewelry and Hollowware he states, “The reliquary, a receptacle in which remains of saints (relics) are kept, is the most significant category of medieval goldsmith’s art” (62). Another category of boxes I found was amulets. Jan Baum, who runs the metals
and jewelry department at Towson University in Maryland, wrote, "I love what I call 'wearable containers': small objects that contain space that can be/are worn on the body. My work comes out of the ancient and archetypal tradition of amulets."

During the 17th and 18th century, the variety of silver boxes made in Europe encompassed everything from spice boxes to dental boxes for holding toothbrushes. Examples of this variety of silver boxes is documented and elaborated on in Eric Delibes's book *Silver Boxes*, where he declared the box as a "versatile article, which has so many differing forms, and has so many ardent admirers" (1). Indeed, the admirers of the box are many, and as illustrated in the myth of Pandora's Box, the intrigue of the box dates back as far as the box itself: "Left alone with the mysterious casket, Pandora became more and more inquisitive. Stealthily she drew near and examined it with great interest...such fine workmanship that it seemed to smile and encourage her" (Guerber).

This mystery that lies at the center of the history of boxes also surrounds the creation of contemporary metal boxes, enabling them to hold a more elevated degree of excitement and anticipation than many other metal creations. Even an artist who mostly does enameling and makes jewelry, like Jan Harrell from Houston, Texas said "I love the secret of boxes--what are they for? What is in them?" In this way, the space on the inside of the box retains as much, if not more, significance as the space surrounding it. Caryn L. Hetherson from Landenberg, Pennsylvania asserted that, "the box is a repository for things whether they are physical things or emotional things. I think that most everyone has a box where they keep things that are important to them and hold special memories whether it is just a cardboard box or a work of art." Whether the box is cradling something ordinary or brilliant, the space heightens the preciousness of its content by providing a beautiful surrounding that protects and hides it.

For me, and for the other metalsmiths with whom I communicated, the box as an idea as well as a physical structure provided an effective parameter to express concepts and influences while simultaneously solving a problem. The history of the box, along with the mystery of its concealing nature, made it an exciting shape to study. In addition, it allowed for the exploration of numerous materials and techniques. As my first focused area of metalsmithing work, box construction has encouraged me to investigate the creation of other metal objects and jewelry such as casting and fabricating rings that incorporate multiple bands and beaded elements. As I orient myself to further undergraduate work, I take with me the advice of Marcia Macdonald, who told me, "Work hard, play hard, and have a life so your work will be about something and then go work some more."

* My project was one of ten conducted during the 2004 McNair Summer Research Institute. The McNair Program facilitates research collaborations between undergraduates and faculty mentors. McNair Scholars write research project proposals and receive funding to take part in a six-week summer research period. The goal of the program is to prepare scholars for doctoral studies. Fine Arts is not often represented within the program, partly because a Master of Fine Arts is the discipline's terminal degree. My inclusion drew from my intention to pursue an MFA/Ph.d (Art History). Because of my...
uniqueness within the group of science and literature majors, I work hard to legitimize and explain my work. My experience as a McNair Scholar has led me to take on endeavors in visual art, particularly metalsmithing, that I never imagined could or would be a supplementation of my studio work.

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Redefining Space: Installation as an Art Form

by

Samantha M. Siker, Department of Art and Design
Faculty Mentor: Dr. Steven F. Terwilliger

Introduction

An increasing interest in the intervention of space has attracted me lately to the forum of installation art: herein the environment as well as the artist's materials are considered an entire work of art. To fully understand the term "installation" before conducting this specific project, I first deconstructed the word. To "install" is to "set up for use or place," whereas "installation" involves the "act of setting up or placing." In installation art, the artist considers the process of placement within space—for example, whether it will reside in a public outdoor space or a privately owned gallery. By selecting public spaces for installation art, the artist attempts to make the work more accessible to the public, an act that also challenges the commodification of art. In fact, installation art often presents the artist's reaction to social or political issues and deliberately reshapes symbols common to modern culture. It also involves viewer participation; observers are typically invited within a space and become engaged with it by using all of the senses. My interest in installation art has led me to fuse many disciplines—including architecture, film, sound, and movement. I was also interested in installation work's site-specificity, temporality, and use of juxtaposed projections that interrelate to form an entire ensemble.

Industrial sites in the Eau Claire community often go unnoticed and overlooked as potential sites for artistic uses. For instance, Banbury Place, originally a rubber factory and currently used as an industrial incubator, presents a sophisticated architectural design, but also symbolizes the once essential economic heart of Eau Claire. The building's historical importance is fascinating, and Banbury Place emanates an almost tragic beauty. Inspired by its striking design textures, I decided to undertake an exhibition that investigated an aspect of its history—an on-site installation involving light and film projections. I wanted to envision Banbury anthropologically, that is, how its decaying buildings visually represented the constant changes in the economy and culture of a small, upper Midwestern community at the turn of the 21st century.

First Ventures into Installation

My work titled Line, constructed on-site at UW-Madison, was created to extend the definition of drawing into an actual mark in three-dimensional space, to divide space in dynamic ways. Line highlights certain architectural features of its housing space, as well
as directs the viewer’s eye to different areas within the room. Another pivotal project, titled *Dividing Space*, constructed at the International School of London, further refined my focus on the relationship of active lines and landscape. This experience, conducted with the collaboration of a seventh-grade class, included intersecting, tying, and pulling fluorescent colored thread into a complex structure. It was meant to be created, interactive, destroyed, and later reflected upon as a complete work of art with the evidence of documentation. Interpretation of the resulting piece was left to each individual student as each worked in groups. Students reported feeling exhilarated and excited by the exercise. I also wanted to create with it a temporality, a deliberate feeling of fragility, vulnerability, an urgency to be seen, and a memory of its presence.

![Image of a water pitcher](Image)

Samantha Siker, *Dividing Space*

Samantha Siker, *Line*

**The Banbury Project Begins**

With these ventures as a foundation, I began researching other Installation artists like Marcel Duchamp, Jean Claude and Christo, Olafur Eliasson, Jessica Stockholder, and James Turrell. Their work helped me formulate ideas on appropriate sites for installations involving the projection of lights and film. Built in 1915, Banbury Place consists of a total of thirteen buildings that originally housed the manufacturing processes of a rubber producer, Gillette Tire Safety; later, Uniroyal Tire manufactured and retread tires here. Banbury’s architecture suggests the influence of the Bauhaus, an early twentieth-century style in which “form follows function.” Bauhaus architects needed to thoroughly understand a building’s function before designing it so that their design would reinforce its function. Banbury’s design has accommodated many functions in addition to its original one, including studio space, factories still in use, and storage.

While exploring Banbury Place, I decided on two exterior locations as sites for my installations. The first location was a large expanse of brick, with aligned windows in rows to the left of the space. The isolation of the brick tower, like a hinge connecting two doors of multiple turquoise glass windows, struck me. The bricked-over “missing win-
dows” beneath the row of windows on the left side of the tower broke the doors’ symmetry and added an interesting variety and mystique to the appearance to the surface. I decided to project two rectangular areas of light on the tower to visually continue the rows of windows, and draw attention to the missing features. I wanted to emphasize a visual metaphor of loss, read both as lost space and a lost time.

The second site selected was the large black silo-like structures that contain the carbon black material, a reinforcing agent in rubber products and a black pigment in paint, used by the American Phoenix Company. What attracted me to the area were the formal qualities of these massive forms and the potential for projections on their curved surfaces. They form one side of a narrow alley with the seven-story American Phoenix building opposite. The area, unlit except for a single doorway lamp, is pitch black on most nights. I had decided to employ a black and white film, the high contrast of which would play against the towers’ black surface with a unique painterly effect that would elude ultimate clarity. One would experience moving and fleeting areas of bright white moving quickly across the mammoth curved silos.

**Execution of the Banbury Project**

For the first site, I decided to use stage lights to project rectangular areas of color onto the building. UW-Eau Claire Theater Department faculty assisted with the technology and logistics of the project. A few problems occurred that interfered with the original projection plan—for instance, the protection of the extremely expensive and potentially dangerous stage lights. We resolved this by projecting from inside a building across the street from Banbury. This solution protected equipment from weather and theft, and insured safety. However, now the distance between buildings and the scale of the lights became essential to plan for; farther distances would require larger lights, and these would have to fit within the window from which I would project. Luckily, the lights fit within the desired windows. Next, the surface and texture of the building onto which I was projecting could pose problems as well. The reddish-brown brick would affect the color, and its texture might diffuse the light and thwart a crisp image. Fortunately, the colors were extremely flexible as there were hundreds of available filters; the projection was just light,
not an image. Lastly, the issue of turning the lights on and off was easily resolved with a set timer that was attached to the theater lights. The most difficult part of the first installation was obtaining permission from the owner of the space from which I needed to project, but with further explanation I received access.

In the second location, where I decided to project a film, I received assistance from faculty in UW-Eau Claire’s Art and Design department. I wanted to collect a montage of images displaying movement to symbolize a progression through time. Reflecting on the use of Banbury Place throughout time, I decided to represent the passing of time with images of traffic, with movement as seen from within a car, and with water. I used the program iMovie first to gain experience and perhaps move on to more sophisticated software. A computer graphics artist and editor friend who works for Fischer Edit in Minneapolis agreed to assist me with filming. I initially captured a lot of footage, then began editing down. Footage included traffic during Minneapolis afternoon rush hour, as well as concrete and passing landscapes while inside the car. One memorable image was the moment right before approaching a bridge, which I repeated backwards and forwards, again and again. And last I shot moving water, and later manipulated repetitions by changing the speed of this image. Staff from UW-Eau Claire’s Bringing Instruction and Technology to Students (BITS) office helped me to covert the film from tape to iMovie format for editing. I created cross-fades, manipulated speeds, reversed images, removed the audio, and converted the entire movie from color to black and white with high contrast. With these desired effects, the film was ready to project onto the carbon black structures.

During the first trial run of the installation, a few problems occurred. At the first site (the brick tower), the greenish colored light projected only faintly. Removing the filters to just reveal rectangular areas of bright light solved the problem. At the second site (the carbon black structures), more problems arose. During the first trial run, the first projector overheated and failed after thirty minutes. I replaced it for the next night. Also, the many atmospheric lights diffused the projected film on the black structures, but this interesting effect rendered the film more subtle and discreet, echoing the environment of the Banbury Place alleyway.

Execution of Nos Vemos: Art, Music, Film

After my first experience with editing film, I sought a more sophisticated editing program that would enable more creative control, like Adobe Premiere Pro. I wanted to superimpose images, construct more complex cross-fades, and attain more dramatic speed alterations. I ventured into a second installation with another artist, Aaron Schasse, who worked with sound mixing as well as film to create an interactive art and music event held at the Stone’s Throw, a local restaurant and night club. The free event would showcase Schasse’s collection of vintage film loops as well as my newly edited and digitized films, all representing movement juxtaposed with music. To achieve a more diverse array of sounds with the moving images, we invited local musicians to perform within the space. We named the project Nos Vemos (“we see”).

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For *Nos Vemos* I decided to capture footage of a foosball game, a more “playful” approach than my more somber and dark earlier film. The color filters on Premiere Pro allowed me to experiment and enhance the green foosball tabletop. I also altered the speeds even further by slowing down dramatically and speeding up erratically. These alterations in speed and color created a near monumental athletic spectacle of plastic, mechanical figures. I projected the earlier and new films on a bright white surface for ultimate clarity of image. The black and white film ran for half the night until the bands started to play, when the foosball film reinforced their movement and sound. I found the interaction electric and the energy exuding from the crowd contagious. The setup proved easy.

**Future Projects**

Installation is ever evolving and offers an engaging venue for artistic expression in which the possibilities are endless. Installing and projecting images within a space can be powerful; it can represent changes within the community and reshape the significance of symbols common to modern culture. The manipulation of these materials within a space—whether it is in a public outdoor space or a privately owned gallery—is up to the artist, viewer, or even environmental chance. The deliberate temporality of installation art refutes the concept of art’s permanence; it refocuses the artist’s and viewers’ attention to the materiality of the work. Installation art is also about the experience and interaction between the viewer, the work, and the artist: without the viewers’ participation or reaction, the artwork remains incomplete.

In future I would like to project the black and white film again, but in a more secluded environment, with the intention of creating a more potent reaction with a dark space and controlled environment while projecting on a white surface. In the previous two installations, I learned how the surrounding environment diffuses light, and I would like to strive for an extremely dark area in which to project. It is interesting how the same projection can have different effects in other environments. I enjoy the mobility and flexibility of installation art and I plan on exploring this in the future.
Tempered Deposition Study of Co on As-rich GaAs(001) c(4x4)

by

Shantih M. Spanton, Kathy Lüdge, Brian D. Schultz, Matthew M. Evans, and Chris J. Palmstrom

ABSTRACT

Studies by K. Lüdge et al. on Co/GaAs intermixing found that at substrate temperatures greater than 150°C during deposition the created Co$_2$GaAs interlayer at the Co/GaAs interface no longer impeded diffusive Co and GaAs intermixing significantly. Minimization of such ferromagnet and substrate intermixing in Co/GaAs(001) was attempted by performing two individual Co depositions during growth. An initial deposition of 5ML of Co was performed on GaAs(001) c(4×4) at room temperature. An anneal to 200°C was then executed followed by additional Co depositions in amounts of 0.5, 3, 5, 10, 15, 25, and 40ML consecutively at either room temperature or 150°C for two distinct trials. Chemical composition and chemical intermixing was characterized in situ with X-ray photoelectron spectroscopy (XPS) at all stages of the experiment.

INTRODUCTION

The realization of spin based, “spintronic,” devices requires efficient injection/ejection of spin polarized carriers and manipulation of the carriers within the devices. Spin scattering at the ferromagnetic metal/semiconductor interface is believed to be a limiting factor. To achieve high injection/ejection efficiencies well-understood, atomically abrupt interfaces between the ferromagnetic metal and semiconductor material is desirable. To determine the cause of spin scattering and subsequently minimize its effects, interfacial structure and chemistry must be well understood.

Previous studies on Co/GaAs(001) by K. Lüdge et al., concluded that at a deposition substrate temperature over 150°C, the formation of the Co$_2$GaAs interlayer at the Co/GaAs interface no longer acted as a significant diffusion barrier for Co and GaAs intermixing. Thus, at a deposition substrate temperature of 225°C, Co deposited on As-rich GaAs(001) appears to diffuse through the Co$_2$GaAs interface layer. None of the deposited Co forms a metal Co overlayer. Scanning tunneling microscopy (STM), low energy electron diffraction (LEED), and reflection high energy electron diffraction

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*a Department of Physics and Astronomy, University of Wisconsin-Eau Claire  
*b Institut für Festkörperphysik, Technische Universität Berlin  
*c Department of Chemical Engineering and Materials Science, University of Minnesota
Tempered Deposition Study of Co on As-rich GaAs(001) c(4×4)

(RHEED) analysis of such Co/GaAs(001) samples showed that increasing deposition temperatures leads to atomically smooth surfaces of good crystalline quality\(^1\). Vibrating sample magnetometer (VSM) measurements showed a decrease in the magnetic anisotropy as the growth temperature increased\(^1\).

While an atomically smooth surface is industrially desirable, the lack of elemental individuality on the sample surface and loss of unique elemental properties, especially those magnetic properties, is not. To make an atomically abrupt interfacial region, necessary for such a product to be viable in spin based devices, Co/GaAs(001) growth techniques must minimize intermixing between the ferromagnet and the substrate yet still create a smooth template for growth upon the surface\(^1\). This study attempts to accomplish the former by performing two separate depositions during growth. Cobalt was grown on GaAs(001) c(4×4) at a substrate temperatures of room temperature and annealed at 200°C. Subsequent additional depositions of Co onto the Co/GaAs(001) sample surfaces were performed at room temperature and 150°C in amounts ranging from 0.5ML to 40ML consecutively. All stages of the experiment were characterized with X-ray photoelectron spectroscopy (XPS) to observe the chemical composition and determine the chemical intermixing.

EXPERIMENT

Sample construction began with the indium bonding of n⁺ GaAs(001) epiready substrates to molybdenum sample holders. Si-doped buffer layers of GaAs (001) 0.5 μm in thickness were then grown on the substrates in an ultrahigh vacuum (UHV) interconnected molecular beam epitaxy (MBE) system\(^1\). Growth occurred at 0.8μm/h at 580°C. Reflection high energy electron diffraction (RHEED) intensity oscillations confirmed an As\(_4\)/Ga incorporation flux ratio of 3:1. To obtain an ordered c (4×4) reconstruction the substrate was then cooled from 580 to 200°C at a rate of 10°C/min once As\(_4\) flux had been reduced 50%\(^1\). The c (4×4) reconstruction was confirmed by RHEED, low energy electron diffraction (LEED), and scanning tunneling microscopy (STM) \textit{in situ} measurements. Co deposition was performed at 0.5 ML/min by a high temperature effusion chamber in the same chamber of the UHV MBE system in which the GaAs growth took place with As background pressure reduced to below 1 × 10^-10 mbar\(^1\). Growth was monitored by RHEED during deposition. Initially 5ML of Co were deposited at room temperature. The sample was then annealed in situ to 200°C. Additional Co depositions were then performed at either room temperature or 150°C in sequential amounts of 0.5, 3, 5, 10, 15, 25, and 40ML. \textit{In situ} x-ray photoemission spectroscopy (XPS) studies of the sample utilized an XPS system with an Al kα x-ray source, an emission angle of 55° and an experimental resolution of 700meV\(^1\). Analysis of the sample by XPS took place \textit{in situ} in a chamber adjoining the growth chamber. The experimental procedure here is a recitation of, and is identical to (with the exception of the secondary depositions), the growth procedure described in Lüdge et al\(^1\).
RESULTS/DISCUSSION

In order to monitor the interfacial reactions of Co/GaAs intermixing, characterization by XPS was performed at all stages of the experiment. Ideally, the addition of the initial cobalt deposition prior to aneal would minimize subsequent ferromagnet/substrate interaction during subsequent deposition [Fig. 1]. Such a minimization would be evidenced in XPS spectral curves with reduced reacted peak intensity as compared to the trials of the previous Lüdge et al study in which no initial cobalt deposition was performed. Core level spectra were taken of both samples (one with later depositions at room temperature, the other at 150°C) prior to any anneal, after the initial 5ML room temperature Co deposition, after the 200°C anneal and at each incremental deposition at room temperature or 150°C respective of the two samples. Spectral data was taken in As2p, As3d, Co2p, Ga2p, Ga3d, and valence band regions. The As-surface component is offset with respect to the binding energy of the bulk component peak by roughly -0.4eV while the reacted As-interfacial component is shifted by 0.5eV relative to the bulk. This result is in agreement with the As-components composition ratios previously obtained by the Lüdge, et. al. group. Similar accordance with the Lüdge, et. al. results was also found with the binding energy level shifts of reacted and bulk components from core level spectra of Ga3d after initial Co deposition.

**FIG 1.** Schematic view of the possible Co/GaAs reactions that may occur during subsequent Co deposition after anneal when 5ML of Co is deposited pre-anneal.
As3d [Fig. 2] and Ga3d core level spectral peaks were numerically analyzed with spectral curve fitting CasaXPS VAMAS processing software. Gaussian/Lorenzian line shapes were used. With the initial deposition of the first 5ML of Cobalt subduction of the surface components in both Ga3d and As3d core level spectra was visible relative to the total peak intensity. Likewise, both Ga3d and As3d core level spectra showed the creation of a reacted layer component after initial Co deposition. Numerical deconvolution of As3d [Fig. 2] core levels split the spectral peak into bulk, surface and reacted compo-

**FIG. 2.** XPS As3d core level spectra of sample trial with secondary Co depositions at room temperature for clean sample (1), sample with 5ML Co deposited at 200°C (2), annealed sample (3), and sample with depositions of 1ML (4), 10ML (5), and 40ML (6) respectively. Numerical deconvolution of the peak is noted: surface component blue, bulk purple and reacted interface green.
nents. For comparison, the normalized intensity ratios of the deconvoluted peaks were compared. At higher Co coverage the ratios of surface to bulk and interface to bulk intensities were greater for the sample for which subsequent depositions were made at 150°C compared to the sample for which additional depositions were made at room temperature [Fig. 3]. The clear trend indicated in this graph illustrates the growth of an interfacial layer with increased deposition at higher temperature as well as an increased amount of As aggregating on the surface in the sample with depositions at 150°C.

The intensity results from the deconvolution of the XPS spectra were normalized by dividing the intensity by the total intensity of the respective Ga3d or As3d peak prior to Co deposition and plotted as a function of Co coverage and growth temperature in Figure 4 [Fig 4]. The Lüdge, et. al.1 SXPS data of Co/GaAs samples grown at 225°C, 150°C, 95°C, and -10°C is also included in Figure 4(a, b, c) for comparison and illustration of attenuation trends. The data presented from the Lüdge, group1 was taken from samples prepared in a manner identical to that of the present discussion, utilizing the same facilities. The growth strategies differed in that our samples (labeled 5ML 150 and 5ML RT in Fig. 4) had an additional Co deposition of 5ML prior to the primary anneal.

**FIG 3.** Plot of surface to bulk and interfacial to bulk component intensities for sample with subsequent depositions at 150°C and for the sample with subsequent depositions at room temperature.

**FIG 4a.** Attenuation curves of As-interfacial component intensities from As3d spectra as a function on Co deposition and time.

The interfacial components in both As and Ga intensities are the reacted components occurring at the interface that contribute to the formation of GoGa-like and CaAs-like phases respectively1. In the intensity curve of the As-surface component [Fig.4c], slowly attenuation for growth below 150°C indicated that all of the As was not covered by the deposition of the Co film during growth, yet some incorporation had occurred implied by the presence of the slight attenuation. The interfacial As-component was weakly attenuated for all growth temperatures [Fig. 4a]. This indicated a fixed amount of a CoAs-like phase continuously segregated near the surface during Co growth. Despite the weak attenuation, the relative intensity of the peak remains strong after the deposition of only a few monolayers of Co and results from As bonding to the Co surface1. By raising
the growth temperature the total As3d signal increased, implying that increasing amounts of As are reacting with the Co layer during Co deposition\(^1\). This is evident in the Ga3d intensities as well. Two trends are evident in the intensity curves of the reacted Ga component [Fig. 4c]. Initially the intensity increased before reaching a maximum peak intensity. This indicated the creation by diffusion of a reacted layer at the interface which increased in size with increased anneal temperature. Once this maximum value was reached, the intensity then decreased for Co coverage in excess of 10ML, indicating the burial of the Ga reacted signal by surface Co deposition of larger amounts.

**FIG 4b.** Attenuation curves of As-surface component intensities from As3d spectra as a function on Co deposition and time.

**FIG 4c.** Attenuation curves of Ga-interfacial component intensities from Ga3d spectra as a function on Co deposition and time.

The disparity in intensity between the curves of the two samples grown at 150°C (one from the Ludge, et. al.\(^1\) group without an initial deposition and the one created for the current study with an initial deposition prior to growth and anneal) indicated a smaller reacted layer occurred at the interface in the sample with the initial 5ML deposition. An simplified view of both intensity curves for the depositions at 150°C is enlarged in Fig. 5. As above the log of the normalized intensities curves for the Ga3d peak of the samples with initial growth of 5ML and subsequent additional growths are plotted versus Co deposition amount. The dashed line represents the attenuation expected for an abrupt nonreactive interface. The intensity curve of the sample whose Co growth was performed at room temperature matches the attenuation expected for pure Co coverage indicative of

**Fig. 5.** Attenuation curves of Ga-interfacial reacted component intensities from Ga3d spectra as a function on Co deposition and time.
the lack of present reactions. Growth at 150°C still produced some reaction but visibly less than the sample without an initial deposition of 5ML of Co when subsequent depositions occurred at 150°C. Note that the slope of the intensity curve for the sample with subsequent depositions at room temperature is close to the slope for a nonreactive interface.

CONCLUSIONS

The Ludge, et. al. study interpreted the reaction as due to Ga outdiffusion from the GaAs. Increased growth temperature increased the mobility of all present constituents and increased interfacial reaction was observed. Limiting this extensive interfacial reaction for deposition at higher temperature is important for the preservation of the magnetic properties of the pure Co and the development of atomically abrupt interfaces. The introduction of an interlayer of annealed Co on GaAs c(4x4) prior to additional Co deposition limited the intermixing of Ga and As to some extent during subsequent Co depositions. Since results were evident but not severe, additional studies would be necessary to fully explore the viability of this procedure as a method for interfacial reaction reduction in component construction.

ACKNOWLEDGEMENTS

- Office of Research and Sponsored Programs (ORSP) at the University of Wisconsin–Eau Claire
- University of Minnesota Materials Research Science and Engineering Center (UMN MRSEC)
- Ronald E. McNair Postbaccalaureate Achievement Program

REFERENCES

Determining Transfer Mechanism(s) of Plasmids via Tn916 Mobilization in Bacillus subtilis, A Work in Progress

by

Jessica L. Spears, Department of Biology
Faculty Mentor: Dr. Sasha A. Showsh

Abstract

Tn916 is an 18kb conjugative transposon. It can transfer between different genera and mobilize plasmids that otherwise are non-transferable. Recent evidence indicates that Tn916 may also transform chromosomal genes via a cell fusion event resulting in homologous recombination of the chromosomes. Dr. Sasha Showsh's prior lab experience suggests that this fusion event is incomplete or does not happen as explained. This study aims to elucidate a different mechanism by which Tn916 mobilizes plasmids and chromosomal DNA; the mechanism on which the most emphasis is placed is an OriT-like sequence hypothesis. The ultimate research goal is to determine and locate similar OriT-like sequences in Bacillus subtilis. Bacillus subtilis strains that have present Tn916 and the test plasmids (ie. pAM401 and pC194) were used as the model for this study.

Introduction

Tn916, a conjugative transposon, has the capability to excise and move within the genome of a host cell. Tn916 is also able to move between bacteria via conjugation. What is even more significant is the ability of Tn916 to mobilize other genes, plasmids for example, during conjugation. The transfer of exogenous DNA by Tn916 has evolutionary implication as well as detrimental consequences of dissemination of antibiotic resistance genes.

There are currently two proposed mechanisms for chromosomal and plasmid transfer in gram-positive bacteria such as Bacillus subtilis. One mechanism suggests that genes located on chromosomes transfer via cell fusion event (Torres et. al., 1990). It was suggested that this fusion event leads to the crossing over of sections of homologous chromosomes (Torres et. al. 1990). If cell fusion occurs it would not be wrong to expect that plasmids would utilize a similar mechanism. Plasmids located in the donor cell would then be expected to transfer to the recipient cell and vice versa (a process called retrotransfer). It was demonstrated, however, that retrotransfer does not occur, indicating that gene transfer cannot be explained completely by the cell fusion hypothesis (Showsh and Andrews, 1996). Chromosomal genes, and thus plasmids, must therefore be transferring via another or other mechanism(s).

The mechanism, for which this study focuses on gaining evidence, is an OriT-like
sequence utilized transfer. OriT regions (or the origin of transfer region) is the site on the DNA where transfer proteins create a nick for replication. During Tn916 mediated conjugation, it is thought that chromosomal transfer can occur due to the presence of Tn916 OriT-like regions that are recognized by Tn916 transfer proteins.

Materials and Methods

Growth media and conditions

Todd-Hewitt Broth (THB) or Luria-Bertani (LB) broth were used in all overnight cultures of B. subtilis and B. thuringiensis subsp. israelensis. Chemically competent B. subtilis SAS701 was transformed with plasmid DNA in a process adapted from Naglich and Andrews (1988b). All growth plates were made with Columbia Blood Agar (CBA) medium. The antibiotics when used were kanamycin (Kan; 200 ?g/ml), chloramphenicol (Cam; 20 ?g/ml), and tetracycline (Tet; 10 ?g/ml).

Filter mating procedure

Filter matings were performed as previously described (Naglich and Andrews, 1988a; Showsh and Andrews, 1992).

Plasmid Extraction and Isolation

All extractions and isolations were performed using QIAGEN Plasmid Midi and Mini kits and the prescribed protocols accompanying those kits (Qiagen, Inc., Chatsworth, CA).

Bacterial Strains

The strains used in this study are described in Table 1. All donor strains are derivatives of B. subtilis SAS701.

<table>
<thead>
<tr>
<th>Strain</th>
<th>Genotype or Phenotype</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacillus subtilis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAS701</td>
<td>trp, [ch::Tn916]</td>
<td>Laboratory Stock</td>
</tr>
<tr>
<td>SAS719</td>
<td>trp, [ch::Tn916], pAM401</td>
<td>Competent Cell Transformation</td>
</tr>
<tr>
<td>SAS720</td>
<td>trp, [ch::Tn916], pAM401</td>
<td>Competent Cell Transformation</td>
</tr>
<tr>
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<td>Competent Cell Transformation</td>
</tr>
<tr>
<td>SAS723</td>
<td>trp, [ch::Tn916], pC194</td>
<td>Competent Cell Transformation</td>
</tr>
<tr>
<td>Bacillus thuringiensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>subsp israelensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAS900</td>
<td>Kan'</td>
<td>Laboratory Stock</td>
</tr>
</tbody>
</table>

Abbreviations: ch=chromosome; r =resistance; trp=tryptophan; Kan=kanamycin; Cam=chloramphenical; Tet=tetracycline

Results

Gel electrophoresis confirmed that the control plasmid, pC194, and the test plasmid, pAM401, were both present in their respective strains. Conjugal frequencies were
calculated as the number of transconjugants per donor. During the first set of trials, pAM401 transfer was not detected even in the presence of Tn916. Tn916 was also not detected in the first trial (Table 2). In the second set of trials, pAM401 transferred with a frequency of \(5 \times 10^{-8}\). The positive control, pC194, transferred with a frequency of \(2 \times 10^{-7}\) (Table 2).

Table 2: Filter mating frequencies

<table>
<thead>
<tr>
<th>Donor</th>
<th>Recipient</th>
<th>Trial</th>
<th>Transfer Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. subtilis SAS719 (Tn916, pAM401)</td>
<td>Bti SAS900</td>
<td>1</td>
<td>Nd (\times 10^{-8})</td>
</tr>
<tr>
<td>B. subtilis SAS719 (Tn916, pAM401)</td>
<td>Bti SAS900</td>
<td>2</td>
<td>5.98 (\times 10^{-8})</td>
</tr>
<tr>
<td>B. subtilis SAS723 (Tn916, pC194)</td>
<td>Bti SAS900</td>
<td>3</td>
<td>2.17 (\times 10^{-7})</td>
</tr>
</tbody>
</table>

* Transconjugants with tetracycline resistance phenotype
b Transconjugants with kanamycin resistance phenotype

Abbreviations: Nd = Not detected

Discussion

Although the data suggests that pAM401 did not transfer in the presence of Tn916, transfer of Tn916 was not detected in the first trial; therefore, it cannot definitively be concluded that Tn916 does not mobilize pAM401. However, the data of further unfinished trials does suggest that Tn916 does not mobilize pAM401. Because the control, pC194, is transferring with much lower than expected frequencies (Showsh and Andrews, 1992 and 1996), conclusions are not as definitive as needed.

Conclusions

Work with pAM401 will continue in the future because data from this research, as well as prior research in Dr. Showsh’s lab (Gosse, 2004), suggest that pAM401 does not transfer in the presence of Tn916. Also pAM401 is a derivative of a well-characterized plasmid making it easy with which to work. Once more definitive conclusions can be reached, known fragments of pUB110 (Showsh and Andrews, 1999) will be cloned in pAM401 and conjugation experiments will be used to determine which fragments or sequences are responsible for the transfer of the once non-transferable pAM401.

References


mob region during Tn916-dependent mobilization. *Plasmid* 41, 179-186.


Karner Blue Butterfly Response to an Aggregation of *Lytta sayi* on *Lupinus perennis*

by

Jodi A.I. Swanson and Dr. Paula K. Kleintjes,
Department of Biology

ABSTRACT

The Karner blue butterfly *Lycaeides melissa samuelis* (Lepidoptera: Lycaenidae) is a federally endangered species found in savanna/barren type ecosystems of New England and the Great Lakes region of North America. We observed sporadic and localized feeding aggregations of *Lytta sayi* (Coleoptera: Meloidae) on *Lupinus perennis* L. (Fabaceae) occupied by the Karner blue during the summers of 2000-2004 in Eau Claire County, Wisconsin. In 2004 we quantified the phenology and behavior of an aggregation (>900 beetles) within a 1,020m² stand of lupine and measured its effect upon adult Karner behavior. The *L. sayi* aggregation formed and dispersed within 11 days with three beetles observed on day one and a maximum of 951 beetles on day seven. By the eighth day of the aggregation, the beetles had consumed 100% of the lupine flowers, 2% of lupine seeds and no lupine leaves. In comparisons of Karner activity before and during the beetle aggregation, Karner males spent significantly less time perching on *Potentilla simplex* (Rosaceae) and more time flying during the beetle aggregation. Karner females spent significantly less time under lupine leaves during the beetle aggregation. Distribution of Karner larval feeding damage suggests adult females avoided ovipositing in areas containing large numbers of beetles.

INTRODUCTION

The US Fish and Wildlife Service placed the Karner blue butterfly *Lycaeides melissa samuelis* (Nabokov) (Lepidoptera: Lycaenidae) on the federal endangered species list in 1992 (Clough, 1992). Karners reside in savanna/barren type ecosystems of New England and the Great Lakes region of North America in association with their sole larval host plant, *Lupinus perennis* L. (Fabaceae) (Blesser, 1993; Dirig, 1994). Interruption of naturally occurring disturbance regimes (i.e., fire, drought, grazing) has contributed to the succession and fragmentation of more than 99% of the historic distribution of savannas and barrens in North America (Nuzzo, 1986; Leach and Givnish, 1999). This is considered the most influential factor responsible for Karner population declines (Clough, 1992). The US Fish and Wildlife Service identified larvae of the painted lady butterfly *Vanessa cardui* and beetles in the family Meloidae as lupine herbivores of concern in the Karner Blue Butterfly Recovery Plan (USFWS, 2001), but little is known about their potential effects on...
Karners. Research suggests competition does not contribute significantly to the shaping of insect communities (Hairston et al., 1960; Strong, 1983). However, due to the restrictive lifecycle of the Karner and diminishing suitable habitat, further investigation of potential competition from lupine herbivores was warranted.

We investigators and others (J. Anklem; pers. comm) witnessed annual aggregations of the blister beetle *Lytta sayi* L. (Coleoptera: Meloidae) feeding on lupine from 2001-2005 at one Karner occupied site in Eau Claire County, Wisconsin. Our objective was to investigate the biology and behavior of *L. sayi* on lupine at this site and whether its presence had an effect upon adult Karner behavior.

**METHODS**

**Study insects**

Karner blue butterflies complete two generations per year. Adults fly from late May to early June (spring) and mid July to early August (summer). Flight lengths average 24-35 days and 25-60 days, respectively. Adult Karners live an average of four to five days (Andow et al., 1994; Swengel and Swengel, 1996). Females oviposit on the leaves and stems of wild lupine and in leaf litter near the base of lupine (Lane, 1999). Summer flight eggs overwinter and hatch the following spring (Haack, 1993). Karner larvae feed on the top or bottom mesophyll of *L. perennis* leaves, leaving the epidermis of the opposite side intact (Blesser, 1993; Swengel, 1995). This results in a characteristic windowpane appearance used to estimate larval abundance (Swengel, 1995). Lane and Andow (2003) found Karner larvae remain near the site of oviposition and often on a single lupine stem.

Blister beetles go through hypermetamorphosis (more than one larval form) with a parasitic larval stage and phytophagous adult stage. Species of the genus *Lytta* complete one generation per year. *L. sayi* adults emerge in late spring and are active until mid-late summer (Selander, 1960). Females create burrows in the soil for oviposition (Selander, 1960; pers. obs.). First stage larvae actively seek out nests of bees (species unknown) where they feed through summer, and overwinter as a non-feeding grub (Selander 1960). Adult *L. sayi* are known to feed on *Prunus* (peach, cherry, plum), *Pirus/monum* (peart), *Rosa* (Roseaceae); *Kolkwitzia*, elder, and *Viburnum dentata* (Caprifoliaceae); *Robinia pseudo-acacia* and beans (Leguminosae); butternut (Juglandaceae); and wheat (Gramineae) (Selander, 1960).

**Study area and design**

We conducted our study May-August, 2004 on private property in the Environmental Quality Incentive Program in Fall Creek, Wisconsin. We chose the site based on past sightings of *L. sayi* and an existing Karner population (J. Anklem, pers. comm). The study area occurred between a native prairie restoration and a forest consisting of white pine *Pinus strobus* L. (Pinaceae), jack pine *P. banksiana* L. (Pinaceae) and red oak *Quercus rubus* L. (Fagaceae). Lupine occupied an area approximately 10-m x 125-m along the forested edge (Figure 1). We established one transect through this area within a 10-m wide band of lupine. Each side of the transect was further divided into twenty-five, 5-m²
quadrats. We numbered the quadrats 1-25 and designated them as north (n) or south (s) of the transect, e.g., 4s or 15n. We visually estimated percent cover of flowering lupine per quadrat. The same researcher (JS) made this estimation before the beetles arrived, during the beetle aggregation and after the beetles dispersed. We counted the number of stems with flowers from 40 randomly chosen clumps of lupine. We estimated percent cover of cinquefoil *Potentilla simplex* M. (Rosaceae), as it was the most abundant nectar source on the site.

We monitored adult Karners in conditions outlined by the Wisconsin Department of Natural Resources in the *Karner Blue Butterfly Habitat Conservation Plan*: partially sunny to sunny skies, temperatures above 60°F and winds less than 20 mph (WI DNR, 2000). We estimated the Karner population size by walking a slow, steady pace along the transect and searching for butterflies within a 5-m arc of the observer. We recorded the sex of each butterfly and the number of the quadrat it occupied. We monitored Karner adult behavior during ten-minute observation periods. We chose the number of observation periods to be proportional (2:1) to the number and sex of butterflies counted on the transect. We attempted to maintain a 2-m buffer between observer and butterfly to minimize disturbance. We followed individual butterflies for 10 min and recorded the proportion of total observation time they spent flying or perching. We also recorded plant species chosen for perching, location on the plant, substrate (*P. simplex* flowers, *L. perennis* leaves, orange hawkweed *Hieracium aurantiacum* L. (Asteraceae), clover *Trifolium* spp. L. (Fabaceae), blackberry *Rubus fruticosus* L. (Rosaceae), grasses, soil), and the quadrat of occurrence. At the end of each larval period, we counted the number of lupine leaves with Karner larval feeding damage on each of the 40 clumps.

We monitored lupine daily for the presence of *L. sayi*. Once the aggregation appeared, we conducted absolute counts of adult beetles 1-3x/day when walking the established transect through the lupine patch. We recorded the number of beetles per stem, mating status (mating or not mating) and the quadrant of occurrence.

**Data analysis**

We used a two-way ANOVA to compare the interaction of (sex *time*) the mean proportion of observation time, male and female butterflies (sex) spent perching or flying, before and after (time) the appearance of *L. sayi* on lupine. We also used a two-way ANOVA to compare the mean proportion of observation time the sexes (sex) spent perching before and during (time) the appearance of *L. sayi* on lupine and their potential interaction (sex*time period) on each substrate. Between subjects effects were tested for each substrate. All analyses were performed with ©SPSS and data were transformed as needed (i.e., arcsin transformation for proportions) to meet the assumptions of ANOVA.

**RESULTS**

Lupine began vegetative growth the second week of April and produced flowers approximately two weeks later. Lupine patches developed from two centers of concentration designated as east and west regions (Figure 1). During the Karner first flight (3-17
June) and the *L. sayi* aggregation (6-15 June) lupine was in full bloom with apical seed development. Nectar sources available during Karner first flight were lupine, cinquefoil, clovers, blackberry and orange hawkweed.

![Forrested edge diagram]

**Figure 1.** Design layout of sampling quadrats in lupine occupied area of the Schofield study site, Fall Creek, WI. Shading represents percent cover of *L. perennis* in each 5 x 5-m quadrat. Quadrats are numbered consecutively 1-25 n (north) or s (south). The east and west regions of the site include quadrats 1-12 and 17-25, respectively.

We observed the first butterfly on June 3, 2004, and the last on June 17, 2004. Total numbers of butterflies per survey ranged from 1 to 6 with a mean of 3.3 (+1.2SD) per survey over the 15-day first flight period. We obtained 56 independent 10-min. observation periods of individual butterflies, 14 of each sex before and during the presence of the *L. sayi* aggregation (Table 1).

<table>
<thead>
<tr>
<th>Females (n=14)</th>
<th>Males (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>East</td>
</tr>
<tr>
<td>Before</td>
<td>92.5</td>
</tr>
<tr>
<td>During</td>
<td>87.6</td>
</tr>
</tbody>
</table>

**Table 1.** Percentage of total perched time both butterfly sexes spent in the east and west regions of the lupine occupied area before and during the formation of the *L. sayi* aggregation, 2-17 June, 2004.
Butterflies perched on a variety of substrates, which were analyzed in the following categories: *P. simplex* flowers, *L. perennis* flowers, *L. perennis* leaves, grasses, soil, other flowers and other forb leaves. The substrates, other flowers and other forb leaves, were used less than 1% of total observation time. The proportion of time butterflies spent perching on all substrates significantly differed by sex (df=7, F=239, p<0.05) but not by time period or sex*time period. The use of lupine significantly differed between the sexes (df=1, F=7.70 p<0.01). Males spent the greatest amount of perching time on cinquefoil flowers (44.3%) before the *L. sayi* aggregation and on lupine leaves (31.2%) during the aggregation (Table 2). Females spent the greatest amount of perching time on lupine leaves before (65.4%) and during (48%) the aggregation. Both sexes significantly reduced their time on cinquefoil flowers (df=1, F=4.9, p<0.05) during the presence of the beetles and increased their use of other flowers (df=1, 8.001, p<0.01). Although both sexes reduced their perching time on lupine leaves during the presence of the beetles, it was not significant.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Period</th>
<th>% Time</th>
<th><em>P. Simplex</em></th>
<th><em>L. perennis</em></th>
<th>Other</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Perching</td>
<td>Flower (a)</td>
<td>Leaf</td>
<td>Flower</td>
<td>Leaf</td>
</tr>
<tr>
<td>Female</td>
<td>Pre</td>
<td>90.7</td>
<td>21.9</td>
<td>0.0</td>
<td>1.0</td>
<td>65.4</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>92.9</td>
<td>11.0</td>
<td>2.0</td>
<td>1.3</td>
<td>48.0</td>
</tr>
<tr>
<td>Male</td>
<td>Pre</td>
<td>53.3</td>
<td>44.3</td>
<td>1.3</td>
<td>1.2</td>
<td>24.2</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>32.8</td>
<td>18.2</td>
<td>0.7</td>
<td>0.0</td>
<td>31.2</td>
</tr>
</tbody>
</table>

Table 2. Mean proportion of total perching time butterflies spent on specified substrates before (pre) and during (post) the establishment of *L. sayi* aggregation (3-17 June, 2004). Substrates with less than 10 observations of butterflies were pooled into a single category (OTHER). 1-Multi-way ANOVA p< 0.05, A between sexes, B between periods per respective substrate.

The *L. sayi* aggregation began with three beetles on 6 June and increased to 951 beetles by 12 June. Numbers diminished to zero by 16 June (Figure 2). The mean (+ SD) number of beetles per lupine stem was 2.0 (+ 0.58) within a range of 1 - 18. Mating individuals composed 32.1% of the population size early in the aggregation (9 June). This percentage declined during a period of heavy rains (9-11 June) followed by a rapid rise in the population on 12 June (Figure 2). By 13 June, beetles had consumed all lupine flowers and began to disperse and the proportion of mating individuals was 24.2%. The majority of the aggregation occurred in the East region (7s and 8s) for most of the aggregation although on the peak day the population was dispersed across the site (Table 3). The mean (+ SD) percent cover of lupine per quadrat before the beetles arrived was 31.8 (+ 1.3) % (Table 3) and declined to 7.8 (+ 0.5) % by 10 June. Before the beetles appeared, the mean (+ SD) number of stems with flowers per clump was 16.2 (+ 8.5) which declined to 2.5 (+ 3.4) by 10 June and to zero by June 13. On June 13, the beetles began feeding on lupine seeds and consumed approximately 2% of the seeds before dispersing off the site.
First brood Karner larvae feeding damage was found on 26 lupine leaves on 15% of the clumps, while second brood feeding damage was found on 63 leaves on 35% of the clumps (Table 3).

**Figure 2.** Total number of *Lythra sayi* adults observed during highest daily counts conducted every day of their aggregation, 2-17 June, 2004. Number of beetles categorized by mating or not mating.

**DISCUSSION**

Our results suggest the presence of *L. sayi* on lupine had an effect upon the flying and nectaring activity of Karner males and the oviposition behavior of Karner females. Although they did not significantly reduce the time butterflies spent perching on lupine they did cause butterflies to move away from areas of lupine occupied by high numbers of beetles. Studies have shown that Karner females preferentially use lupine growing in shade for oviposition and that shaded lupine is best suited for larval fitness (Grundel et al., 1998; Lane, 1999; Lane and Andow 2003). We found that the majority of larval feeding damage from both first and second broods occurred closest to the forested edge, under maximum available shade. The exception was that 38.4% of the total first brood Karner larval feeding damage occurred in a single quadrat (6s). The proximity of 6s to cinquefoil, their preferred adult nectar source, is a possible explanation for this observation. There was no Karner larval feeding damage from the summer brood on lupine in the same region (quad-rats 6s, 7s or 8s). Adult females that laid these eggs were flying during the beetle aggregation, which suggests they avoided the beetles when choosing oviposition sites. Oviposition site selection by adult butterflies is one of the most important factors influencing larval fitness as it determines the quality of host plant available to the larvae (Rausher, 1979; Grundel et al., 1998). We suspect that Karner females avoided disturbance by *L. sayi* and minimized oviposition on lupine growing in full sun to increase larval survival.

According to the resource concentration hypothesis, specialist herbivores remain in areas of dense host plant cover (Root, 1973). Our data support this hypothesis for Karners spent the majority of total perching time in the eastern region of lupine concen
tration. This was the larger of two centers of lupine concentration and had the highest percent cover of cinquefoil. This area, however, also contained the majority of the L. sayi population which leads us to conclude that the disturbance from L. sayi was not enough to overcome the butterfly’s tendency to remain in a concentrated area of larval host plants.

There is conflicting evidence as to whether lupine is a nectar source for Karner. Grundel et al., (2000) states that lupine does not contain floral nectaries and therefore is not a nectar source for butterflies, although several sources cite lupine as a potential nectar source (Dirig, 1994; Blesser, 1994b; Swengel and Swengel, 2002). Regardless of the level of use, researchers agree that Karner adults are not dependent on lupine for nectar and will use a variety of plant species. Our study indicated that Karner spent little time on lupine flowers and the data support earlier studies that rank cinquefoil as one of

Table 3. Observational data recorded per 5-m² sampling quadrat (n=50) of the designated study area.

<table>
<thead>
<tr>
<th>Q</th>
<th>% Mean % of L. sayi population</th>
<th>% Cover P. simplex</th>
<th>% Cover L. perennis 6 June</th>
<th>% Cover L. perennis 11 June</th>
<th>% Larval damage sites pre L. sayi (n=26)</th>
<th>% Larval damage sites post L. sayi (n=63)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0.8</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
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<td>0</td>
<td>75</td>
<td>5</td>
</tr>
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<td>3</td>
<td>0</td>
<td>4.9</td>
<td>0</td>
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<td>5</td>
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<td>4</td>
<td>3.2</td>
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<td>5</td>
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<td>0</td>
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</tr>
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<td>6</td>
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<td>7</td>
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<td>39.4</td>
<td>0</td>
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Q = quadrat number; N S = north or south of transect.
1L. sayi (mean percentage of total counts); 2P. simplex (visual estimate of percent cover before L. sayi aggregation (6 June, 2004); 34L. perennis (visual estimate of percent cover before L. sayi aggregation (June 6) and the day before peak population counts (June 11); 56Larval damage (percent of total Karner larval feeding damage observed on L. perennis clumps resulting from spring (pre L. sayi) and summer (post L. sayi) broods).
the most frequently used nectar plants (Bleser, 1994; Grundel et al., 2000; Swengel and Swengel, 2002).

We did not observe *L. sayi* feeding on any substrate aside from lupine flowers and seeds. This includes flowers of cinquefoil, even though it is in the family Rosaceae, a known food plant family for *L. sayi* (Selander, 1960). Of importance was that *L. sayi* did not feed on the leaves of lupine and therefore were not in direct competition with Karner larvae for food. However, they may have an indirect impact on larvae and adults since mass consumption of biomass by insects can impact the expansion of plant populations by reducing seed production (Carson and Root, 2000).

*L. sayi* adults were docile and not easily disturbed by observers. They remained feeding on the same flower(s) during surveys. We believe this, coupled with the ease of sighting due to the large size of the beetles (13-25 mm) (Selander, 1960; pers. obs), reduced the chance that we missed or made multiple counts of a beetle. *L. sayi* aggregation formation, mating behavior and the ability to consume copious amounts of vegetation in a short period of time are consistent with the feeding behavior of other meloid species (Selander, 1960; Church and Gerber, 1977; Snead and Alcock, 1985; Evans, 1990; Chandel et al., 1996; Nead et al., 1996). Although we captured a noteworthy phenomenon of >900 *L. sayi* aggregating upon and deflowering an entire field of lupine, the minimal size of both the study site and the Karner population limited the conclusiveness of our results. In addition, the study units (quadrats) were not independent and the number of Karner surveys were limited by a period of heavy rain mid-way through the beetle aggregation. Even with these caveats in mind, we conclude that the presence of *L. sayi* potentially disturbs adult Karners. Of further note, is that a second site (within 10 miles), which had sporadic observations of *L. sayi* on lupine in the past (1999), no longer sustains a population of Karner blues. Albeit, all-terrain- vehicle (ATV) activity degraded the site and contributed to the decline of lupine.

Minimum viable population studies have shown that Karner populations with spring broods of < 250 individuals should not be considered viable for conservation purposes and those with < 100 individuals have little chance of survival (Schwitzer, 1994). Our current study population is small as demonstrated by the low population counts of adults and minimal observed amount of larval feeding damage. Regardless of the minimal level of disturbance from *L. sayi*, this Karner population is precariously close to extirpation.

ACKNOWLEDGMENTS

The authors thank Jane Anklam, Scott Thiel, Chuck Bomar, Patricia Quinn, Monty Ernst, Pamela Golden, Tom Schofield, Gordon Waller, Creanna Cote, Dustin VanOverbeke and Jack Swanson for their assistance and advice, and Marla Spivak for review of the manuscript.

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Responding to a Hypothetical Extra-Pair Involvement: Sex Differences in the Nomination of Cues of Sexual Infidelity

by

Nalee Xiong, Department of Psychology
Faculty Mentor: Dr. April Bleske-Rechek

Abstract
In a novel test of the hypothesis that men and women differ in the weight they give to cues of sexual versus emotional infidelity, 156 undergraduate students were asked to list pieces of evidence that would lead them to believe that their partner was involved with someone else. The nature of the extra-pair involvement was intentionally ambiguous, employing the expectation that if the sexes differ in their weighting of cues, the sexes would differ in the extent to which they nominate sexual versus emotional cues as evidence of extra-pair involvement. As expected, men’s first cue involved explicit sexual evidence more frequently than did women’s. Further, a greater proportion of men’s versus women’s cues referenced sexual evidence, despite the fact that, on average, men nominated fewer cues. We documented no sex difference in the nomination of emotional cues. Replication of this study in a sample of married and/or older couples may provide a more ecologically valid test of whether women weigh cues of emotional infidelity (e.g., decreased or redirected investment of emotional and financial resources) more heavily than do men.

Introduction
According to Robert Trivers (1972), there are two processes which guide sexual selection: intersexual selection (mate choice) and intrasexual selection (competition for mates). The obligatory parental investment results in determining which sex selects and which sex competes. This model can be seen with animals: male birds, for example, are more colorful because they compete with other males for mates, whereas female birds are choosier in their selection of a mate. The true test to this theory is whether or not the same phenomenon occurs when males are the more investing sex. Seahorses are an excellent example of this investment role reversal. Male seahorses are choosier in whom they mate with, and female seahorses are more competitive for mates.

These reproductive sex differences are also found in humans. Due to a greater parental obligatory investment, human females are choosier in selecting a sex partner. Females will want to select a sex partner who will be willing to invest more than the male obligatory expectations. La Cerra (see Buss, 2004) conducted a study that found this to be the case. Photos were taken of a male and female in five different scenarios: (1) stand-
ing alone, (2) interacting with child, (3) ignoring crying child, (4) facing a child (neutral condition), and (5) vacuuming (domesticated condition). Male participants were to rank which picture of the female was more attractive, while female participants ranked the ones of male subjects. The study indicated that females ranked the male interacting positively with the child highest and ranked the male interacting negatively with the child lowest. The male participants, on the other hand, ranked all scenarios with the female equally high, indicating that the male participants found the female equally attractive regardless of what she was doing. Other studies have also found this phenomenon to occur. Buss and Schimidt (1993) found that it was essential to women to have a prevalent emotional component in the relationship before consenting to sexual intercourse, whereas men were more willing to have sex without the emotional component. According to Townsend (1995) 76% of men compared to only 37% of women would still be willing to have a sexual relationship with someone they would not necessarily want to be involved with emotionally.

Since there is obvious evidence of reproductive sex differences, is it farfetched to believe that there will be reproductive sex differences that select for psychological sex differences? Jealousy is an emotion that plagues all humans. This should not be surprising since statistics indicate that 20% to 25% of married individuals have participated in extra-marital sex (Atkins, Jacobson, Baucom, 2001). Although both males and females are guilty of this act, there are underlying sex differences. For example, Spanier and Margolis (1983) have found that women who practice infidelity have a tendency to be more emotionally invested in the extra-pair relationship than unfaithful men. In a similar study, it was found that men were more likely to have “sex-only” affairs in comparison to women, whereas women were more likely to have “emotional-only” affairs in comparison to men (Glass & Wright, 1985). Many studies have also found that more men than women are involved in extra-pair relationships (e.g., Greeley, 1994; Laumann et al., 1994; Wiederman, 1997; Atkins et. al., 2001). Pines and Friedman (1998) also found that men in comparison to women were more likely to fantasize about extra-pair involvement (Mm = 4.8, Mw = 4.1; F = 5.0; F(1,119) = 3.1, p = 0.01). Interestingly enough, they also found that although women were found to support monogamy more strongly than men, men more often than women were more likely to end a relationship due to jealousy.

Don Symons (1979) first proposed the question: “When should men and women feel their relationship is threatened?” Because of the fact that human females are fertilized internally, it was predicted that males, when exposed to cues that historically were linked with paternal uncertainty, such as sexual infidelity, would become jealous. It has been estimated that 9% to 13% of children have fathers that are not genetically related to them (Baker & Bellis, 1995; Buunk et al., 1996). Females were predicted to be jealous when exposed to cues that historically were linked with diversion of partners’ resources and investment, such as would be found with emotional infidelity. Several studies have supported this evolutionary perspective on jealousy (e.g., see Buss, Larsen, Westen, & Semmelroth, 1992; Buss, Shackelford, Kirpatrick, Choe, Lim, Hasegawa, et al., 1999; Schützwohl & Koch, 2004; Shackelford & Buss, 1997).
This research was first pioneered by David Buss. These self-report research projects set up a scenario in which the participants were asked to choose which situation would upset them more. Below is an example of a scenario:

Please think of a serious or committed romantic relationship that you have had in the past, that you currently have, or that you would like to have. Imagine that you discover that the person with whom you’ve been involved became interested in someone else. What would upset you more? Please circle only one.

1. Imagining your partner forming a deep emotional attachment to that other person.
2. Imagining your partner enjoying passionate sexual intercourse with that other person.

The results from these studies supported the hypothesis that males would be more upset by sexual infidelity and females by emotional infidelity.

However, there was a possible significant confound on how the situations were being interpreted by the participants. It was criticized that emotional attachment could infer a sexual relationship, and the act of sexual intercourse could be an expression of a development of an emotional attachment (e.g., DeSteno & Salovey, 1992; Harris, 2000). This resulted in another study involving several scenarios in which the participant was forced to make a choice between emotional and sexual infidelity when they were concurrently occurring. This alternative explanation is better known as the double-shot hypothesis. Despite these efforts to refute the evolutionary perspective each of these studies indicated that males were more upset by sexual infidelity than females and vice versa. (It must be noted that these results do not indicate that males are not distressed by emotional infidelity and females are not distressed by sexual infidelity.)

Although these studies indicate that Symons’ hypothesis may be true, they do not directly answer the original hypotheses: (1) that males more than females have evolved a sensitivity to cues of sexual infidelity, and (2) that females more than males have evolved a sensitivity to cues of emotional infidelity. Our research hopes to use a direct test of “cues” to infidelity in order to determine if the initial hypotheses stand. If males are more sensitive to cues of sexual infidelity, then they should respond to their partners’ ambiguous involvement with another by looking for evidence linked to sexual involvement with the other. If females are more sensitive to cues of emotional infidelity, then they should respond to their partners’ ambiguous involvement with another by looking for evidence linked to emotional attachment to the other.

Materials and Methods

Participants

Participants included 156 undergraduates (71 males, 85 females) from a regional public university. The majority of participants were Caucasian, with a mean age of 20.08 years and an age range of 17 to 34 years (mode = 18). Approximately 81% of participants reported previous or current long term relationship involvement.
Setting

Two samples were taken. The first sample was from an upper-level psychology course, which consisted of juniors and seniors, and the second sample was taken from an on-campus recreational area, which consisted mainly of freshman and sophomores.

Method

Participants were given a one-page survey that set up a scenario as follows:

Imagine that you are in a committed, long-term relationship. You are concerned, however, that your partner has become involved with someone else. What specific cues, or pieces of evidence, would lead you to believe that your partner is involved with someone else?

They were then given 10 blank spaces in order to nominate cues. Upon completion of these nominations, they reported their sex, age, sexual preference and relationship history (whether they have cheated or been cheated on). The total participation time took approximately five minutes. After finishing the complete survey, participants were given the option of receiving a piece of candy as a form of reward.

Coding

Participants nominated a total of 915 cues. The researchers and a male research student categorized all cues (including redundancies) into 20 lower-order categories over a one-month period. After creating the lower-order categories, the researchers followed Shackelford & Buss (1996) for placing lower-order categories into one of three higher-order categories: Sexual, Emotional, or Other. A description of these categories is displayed in Table 1.

<table>
<thead>
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<th>Table 1. Lower-order categories comprising each higher-order category (sexual, emotional, and other) and two sample acts within each lower-order category.</th>
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</thead>
<tbody>
<tr>
<td><strong>SEXUAL</strong></td>
</tr>
<tr>
<td>Less sex</td>
</tr>
<tr>
<td>Doesn’t want to have sex</td>
</tr>
<tr>
<td>Doesn’t want to have sex as often</td>
</tr>
<tr>
<td>Sexual or physical evidence</td>
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<tr>
<td>I catch them in the act</td>
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<tr>
<td>Smells like cologne/perfume</td>
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<tr>
<td>Enhances appearance</td>
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<tr>
<td>More concerned with appearance</td>
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<tr>
<td>Exercises a lot</td>
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<tr>
<td>Behavior suggests other’s influence</td>
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<tr>
<td>or change in routine</td>
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<tr>
<td>Hangs out with new friends</td>
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<tr>
<td>Dresses differently</td>
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*Note: Although only 5 lower-order categories for “Other” are shown here, there are a total of 11 lower-order categories. Those not mentioned are as follows: more time with others of opposite sex, derives me about who-what-whens, previous history of cheating, accuses me of cheating, develops problems, too vague or inappropriate.*
Results

Pearson chi-square analyses were conducted to investigate sex differences in cue nominations. As shown in Figure 1, men were more likely than women to nominate a sex-linked cue as their first cue (and women more then men tended to nominate an emotional-linked cue as their first cue), \( \chi^2(1, N = 102) = 2.62, p = .11 \). The effect was small, Cramer's \( V = .16 \). This pattern was also prevalent in the second cue (Cramer's \( V = .10 \)), but was not significant.

Figure 1. Percent of men and women whose first cue was sexual; and percent of men and women whose second cue was sexual.

Note. For analysis of the first cue, 56 responses that were neither sexual nor emotional (they were “other”) were coded as missing. This left a sample of 47 cues for men and 55 cues for women. For analysis of the second cue, 68 responses that were neither sexual nor emotional (they were “other”) were coded as missing. This left a sample of 40 cues for men and 50 cues for women.

Men \((M = 5.13, SD = 2.15)\) nominated fewer cues or pieces of evidence in response to the hypothetical extra-pair involvement than did women \((M = 6.39, SD = 2.17)\), \( t(154) = -3.63, p < .001, d = -.59 \). As displayed in Figure 2, however, a greater percentage of men’s than women’s nominations were sexual, \( t(154) = 2.07, p < .05, d = .33 \). Men and women did not differ in the percentage of cues given that were emotional \((p = .20)\).

Figure 2. Percent of all cues nominated that were sexual, and percent of all cues nominated that were emotional, by sex.

Note. Although women nominated more cues than men overall, a greater percentage of men’s nominated cues were sexual.
Across the sexes, participants nominated more emotional cues (M percentage = 40.35, SD = 24.16) than sexual cues (M percentage = 17.19, SD = 18.99), paired t(158) = -8.06, p < .001, d = -.64. This effect was replicated within each sex, ps < .001. Across the sexes, the percentage of sexual nominations was negatively correlated with the number of emotional nominations (r(158) = -.39); and this effect replicated within the sexes, ps < .001. Individuals who nominated more sexual cues also offered fewer emotional cues.

Discussion

In this study, it was found that although men nominated fewer cues or pieces of evidence overall than women did, a greater percentage of the cues they did nominate were sexual (e.g., I caught them in the act or They don't want to have sex with me anymore). Men’s first cue was also more likely to be sexual than was women’s first cue. This finding may be of practical significance because it is plausible that the participants’ first cue is most representative of their instantaneous reaction to hypothetically thinking about their partners’ extra-pair involvement with someone else. This ambiguous approach may be a better indicator of which type of infidelity the participants are more upset by in comparison to the forced-choice approach.

The study did not find that women nominated a greater percentage of emotional cues than did men. This may be a product of a primary limitation of this research — the use of a college sample. Acts that are fundamentally indicative of an emotional infidelity, such as those within the category decreased or redirected financial investment, were nominated infrequently in the sample of financially dependent, unmarried young adults. It is projected that taking a community sample will remove this limitation and provide a stronger test of the hypothesis that women are more sensitive than are men to cues of a partner’s emotional involvement with another. (A community sample study is currently in the process of being collected from a sample of middle-aged men and women.)

Another limitation of this research and other research on infidelities in general (Shackelford & Buss, 1997) is that the sexual categories were more easily defined than were the emotional categories. It is suspected that this may be another explanation for this study’s inability to empirically show that women are more likely to nominate cues of emotional infidelity than are men. Again, it is possible that this issue may also be alleviated somewhat with the use of a sample of middle-aged married men and women.

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