ASTRA
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From Chancellor Brian Levin-Stankevich

As the 2007-08 academic year opened, I called upon the UW-Eau Claire community to find ways to attract, enroll and graduate quality students, especially students of color and first-generation students, and to open our campus more effectively to adult learners. Our McNair Program provides a persuasive example of how recruiting for diversity enhances quality. McNair’s learning community does not mirror the present undergraduate student body, but instead offers a glimpse of its future: 27 percent of McNair participants are multicultural students, 94 percent are first-generation, and 20 percent are older-than-traditional age learners. The articles that fill this volume of Astra present these students’ capabilities as second to none. And as their impressive track records on graduate school admission and postbaccalaureate funding testify, doctoral institutions from across this country (and others) agree.

At a recent academic summit American and European leaders in higher education drew up a vision for universities in the 21st century. “Universities,” they said, “must recognize their unique responsibilities to and opportunities in their communities, regions, and the larger global society by affirming that teaching is a moral vocation, scholarship is a public trust, and service is a major institutional obligation.” As the Academy’s future professionals the McNair Scholars of this double volume appear ready for the task. Ben Sykora’s work, for example, promises efficiencies for local microchip manufacturers, just as Julie Ackerman’s collaboration provides direct and immediate benefits to local children diagnosed with autism. Jacquelyn Dumin’s picture of rural Wisconsin women in Butternut and Park Falls during the Second World War adds to the state’s public history. Five Scholars explore the situations of immigrants—most to the Upper Midwest. Serena Davis sketches the more recent impact of Latinos on the St. Paul cityscape, while Tammy Goss describes how the work of Slovenian Frederic Baraga in the 19th century assists the vitality of Wisconsin’s regional Algonquin languages in the 21st. Zach Stensen’s “Augusta Portrait Series” explores how the area leaves its mark—literally—on his hometown’s Scandinavian-American residents. Erin House’s article on Turkish “guest workers” in Germany reveals similarities among migrant workers in a global economy, whether the host country happens to lie in Europe or North America. Finally, Alison Welin’s work queries why “immigrant” plant species enjoy an edge over indigenous prairie seedlings.

Teaching as a moral vocation is evident in Chad Conrado’s detailed review of British gas warfare in World War I, a presentation that provokes its readers to larger ethical questions. Brittan Grygg’s study of cross-sex friends probes how evolution may assist or resist ethics when a friend considers the purpose of a relationship. And while burnout sounds more a physical than a moral issue, Stephanie López’ research focuses on athletic trainers’ responsibilities to their apprentices.

This Astra’s five examples of pure research—Brandon Barrette’s work on Keplerian orbits, Carolyn Otto’s moduli spaces, Corey Schuster’s eigenfunction expansions, Elizabeth Smith’s work on Lewis acids, and Carly Wickham’s manipulation of hamsters’ sleep and estrous cycles—are less easily accessible to lay readers, yet no mathematician, chemist or zoologist would deny the service their contributions afford the respective disciplines.

The McNair Scholars of Astra VI/VII represent the way of the new UW-Eau Claire. As researchers they did not accept a “definitive” explanation or process or approach, but instead questioned it. They sought something truer and better, and committed themselves diligently and carefully towards that end. Along with the staff of the McNair Program, I applaud their contribution to the public trust and to the service they render our community.

This *Astra* marks the completion of the second four-year cycle of the Ronald E. McNair Postbaccalaureate Achievement Program at UW-Eau Claire. Eight years and 99 Scholars later this director recalls fondly the adventure’s beginnings: for example, that Crane Foundation visit in the summer of 2000 when Jill Sporrong and Katie Thornberg explained the characteristics of oak savannahs, and when at the conclusion of the first Summer Research Institute Toby “Mr. Cabaret” Yatso played emcee at the Grande Finale out at Hobbs Observatory. This past spring two members of that initial cohort finally achieved critical *termini* on their respective academic journeys... Jeff Miller at the doctorate and Israel Howard at the baccalaureate. (Yes, those who know Israel understand full well why I could not resist this juxtaposition of heroic efforts!) Teresa Jentzsch and Anthony Ratkovich of the first cohort chose the U of M for graduate school and thereby unknowingly established the “McNair Twin Cities Enclave.” This home-away-from-home later claimed Aaron Broege (2), Katie Hawkins (2), Jack Kollwitz (2), Mainue Moua (2), Meng Yang (2), Jimmy Gosse (3), Kristina Hall (4) and Jodi Swanson (5)—and re-claimed Anastasia Karabotsov (1). Of course, rumor has it that our “mystery men” Kyle Floren (1) and Tim Wenzel (4) also inhabit that appealing metropolis.

Lest one think, however that most “first flight” McNair Scholars remained close to alma mater, let me cite Kevin Bartig’s graduate school odyssey from Wisconsin to North Carolina, to Great Britain, to Russia, and back to North Carolina; or Val Boyarski’s journeys on the high seas of Polynesia, the high slopes of the Colorado Rockies, and the high dunes of Arizona’s deserts. Nicki Weinfurtner has surely traveled back to Spain as part of her graduate program at UW-Madison, but I wonder if her friendship with Anastasia led her on from those facsimiles of Zeus and Poseidon under which we three stood at Wisconsin Dells to the real monuments of Greece. And Emily Bauer, at one of the planet’s hubs in New York City, walks the world by simply traversing neighborhoods.

Many excellent projects developed throughout the eight years of McNair, from first cohort Melissa Garney’s survey of invertebrates in Lake Hallie (No, I did not overlook you, Melissa!) to eighth cohort Ka Lor’s survey of aquatic plants in Pine Lake. A colleague pointed out to me last year that I have the best job at UW-Eau Claire; and while this researcher’s immediate reaction involved speculating on appropriate means to measure “best,” I enthusiastically agreed, then and now, to the persuasiveness of that hypothesis. What great, inspiring students! What wonderful, generous faculty mentors! What a terrific, meaningful journey!
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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A Comparison of Constant Prompt Delay and Simultaneous Prompting Procedures on Teaching Acquisition Skills to Young Children with Autism

by

Julie A. Ackerlund, Sara M. Weinkauf, and Dr. Kevin P. Klatt, Department of Psychology

Abstract

Two of the effective procedures for skill acquisition are simultaneous prompting and constant prompt delay. Simultaneous prompting consists of immediately prompting a correct response to an instruction. With constant prompt delay, the prompt is delayed to allow for independent responding. The purpose of this study was to compare the procedures to determine which was more effective and efficient for skill acquisition in children with autism. Both procedures were effective in teaching skills, but the constant prompt delay was more efficient in terms of number of trials and sessions for most programs and resulted in more teaching errors in all programs. Half of the programs had more probe errors in simultaneous and half in constant prompt delay.

Introduction

Children with autism have many skill deficits. The most common are seen in the areas of communication, social interaction, and self-care skills. The goal of behavioral therapy is to teach these skills with the hope that these children will be able to enter kindergarten and be as indistinguishable from the other "typical" children as possible. In order to do this therapy needs to begin early, and it is imperative that therapists know the most effective and efficient methods of teaching these important life skills.

Skill acquisition for a young child with autism is extremely difficult and must be done efficiently and effectively. It is often necessary to help the child acquire skills by providing a prompt of the correct response in the early stages of a specific skill. A potential problem with chronically providing a prompt when necessary is that it can result in the child becoming prompt dependent, meaning that the child becomes unable to respond correctly without the assistance of the prompt. The teacher's goal must be to successfully transfer stimulus control from the prompt to the instruction and allow the child to respond to the instruction correctly and without assistance. Different prompting methods have been previously investigated to determine how efficient and effective they are in terms of teaching new skills and the transfer of stimulus control with children with various developmental delays, but as of yet no investigations exist for children diagnosed with autism.

Touchette (1971) demonstrated the transfer of stimulus control with a constant prompt delay procedure. In the constant prompt delay procedure the child was given time to respond independently before prompt delivery. Since Touchette (1971), many other studies have shown that the constant prompt delay procedure is effective for teaching various skills, such as aquatic skills (Yılmaz, Birkan, Konukman & Erkan, 2005), snack and drink preparation (Bozkurt & Gursel, 2005), employment skills (Chandler, Schuster, & Stevens, 1993), spelling (Coleman-Martin & Heller, 2004), multiplication (Koscinski & Gast, 1993, and Morton & Flynt, 1997), sight words (Schuster, Griffen, & Wolery, 1992), word definitions (Schuster, Stevens, & Doak, 1990), and leisure skills (Wall, & Gast, 1997).
Another type of prompting is the simultaneous prompting procedure, which involves a 0-second prompt following every instruction. The child is allowed to independently respond only in test sessions to determine if stimulus control has been transferred from the prompt to the instruction. Simultaneous prompting procedures have demonstrated success in teaching various skills, such as pointing to numerals (Akmanoglu & Batu, 2004), naming relatives (Akmanoglu-Uludag & Batu, 2005), identifying occupations (Dogan, & Tekin-Iftar, 2002), word recognition (Gibson, & Schuster, 1992), sight words (Schuster, Griffen, & Wolery, 1992), community signs (Tekin-Iftar, 2003), object identification (Tekin-Iftar, Acar, & Kurt, 2003), dressing skills (Sewell, Collins, Hemmeter, & Schuster, 1998), and a variety of discrete trial tasks (Birkman, 2005).

Only a small amount of research has focused on comparing the constant prompt delay and simultaneous prompting procedures (Morton & Flynt, 1997; Riesen, McDonnell, & Johnson, 2003; Schuster, Griffen, & Wolery, 1992; Tekin &Kircaali-Iftar, 2002). The studies have found that both procedures can be effective in teaching new skills to people with a variety of developmental disabilities. Some studies have found that the procedures differ in efficiency, while others have found no differences in efficacy. Schuster, Griffen, and Wolery (1992) found that simultaneous procedures were more effective and efficient for teaching sight words. Morton and Flynt (1997) found that there were no differences in how efficient or effective either procedure was in teaching multiplication facts to individuals with disabilities. Tekin and Kircaali-Iftar (2002) found that both procedures were effective for teaching skills, but the simultaneous prompting procedures were more efficient in overall training time and resulted in fewer errors. Riesen, McDonnell, and Johnson (2003) found that simultaneous procedures were effective for all four participants and the constant prompt delay procedures were effective for three out of the four participants. Two of the participants acquired skills faster in the simultaneous condition and the other two participants acquired skills faster in the constant prompt delay.

Both simultaneous and constant prompt delay have been shown to be effective in teaching a wide range of tasks. However, research has not yet been conducted with young children diagnosed with autism as the sample participants. The purpose of the current study is to compare simultaneous prompting and constant prompt delay procedures to determine which is more effective and efficient in teaching new acquisition skills specifically to young children diagnosed with autism.

**Method**

**Participants**

The participants in this study were two female children and five male children diagnosed with autism with ages ranging from two years to six years old. All of the participants were receiving intensive behavioral therapy for either 30-35 hours a week in-home or four hours a week at a university autism clinic.

Skills were identified from each child's overall therapy plan before conditions began. For participant 1, Nick, and Participant 2, Brian, an expressive adverb program was used to compare simultaneous and constant prompt delay procedures. For Participant 3, Ellie, an expressive spelling as well as an expressive addition program were used. For Participant 4, Seth, an expressive addition program was used. For Participant 5, Molly, both receptive tacting and community helper receptive tacting programs were used. For Participant 6, Mark, multiple programs were used that included selecting associated pictures, expressive before and after, and expressive opposites. For Participant 7, Derek, an object imitation program was used to compare the two procedures.

**Settings and Materials**

Research sessions were conducted at the university autism clinic, if that was the child's primary therapy setting, or in the child's home, if that was the child's primary therapy setting.
study was conducted at the university autism clinic for three of the participants. The study took place for the remaining four participants in their homes. All trials during sessions were recorded on the same basic data sheets regardless of setting. Preferred toys, food, and beverages were used to reinforce the children during the sessions. Picture cards or flashcards were also implemented if called for by the specific program on which the child was working.

Reliability
Interobserver agreement of the dependent variables was collected during at least 9% of sessions for each participant; this ranged from an overall percentage of 88 to 100%. Procedural fidelity was also calculated. At least 15% of sessions had procedural fidelity recorded and ranged from 88 to 100%.

General Procedures
An alternating treatment design was implemented using three conditions: a simultaneous prompt condition, a traditional constant prompt delay procedure, and a modified prompt delay procedure. The simultaneous condition was always compared with one of the two constant delay conditions, while the two constant delay conditions were never compared to each other. Due to time constraints only three programs implemented a second phase of the experiment.

Every day there were two teaching sessions: one would always be the simultaneous procedure, while the other would be the traditional or modified constant prompt delay procedure, depending on which had been randomly assigned to that program. After completion of one set of targets in one constant procedure the other constant procedure would also be compared to the simultaneous procedure using different targets, but the same overall program.

Counterbalancing occurred every day prior to the session to ensure that the order of teaching sessions was alternated; this meant if the simultaneous condition had been taught first the day before, then the constant delay condition would be taught first on the following day. The teaching order of the specific targets within each program was also randomly assigned each day to ensure that targets were not taught in the same order consistently. Five trials of each target were taught in the simultaneous condition (ranging from 1-5 targets) for a total of 5-25 trials, and five trials were taught for each target in the constant prompt condition (ranging from 1-5 targets) for a total of 5-25 trials. Each session occurred within the child's regular therapy session.

Baseline and Probe Procedures
Baseline data was taken during one session prior to program implementation and consisted of giving an instruction (e.g., "What is it?"). The participant had the opportunity to respond. If the participant gave the correct response (e.g., correctly identified a picture of a cat as "cat or kitty") within five seconds of the presentation of the instruction, the teacher delivered the reinforcement in the form of praise (e.g., "Good job!"). If the participant erred or did not respond within five seconds of the instruction, the trial was terminated. If the child consistently mastered targets in the program it would not be used for our research. The researchers chose programs where the child correctly answered 1 or fewer targets. All targets for all conditions were probed during baseline prior to beginning any teaching sessions.

Probe sessions were conducted every research session except the first teaching session that followed the baseline probe session. Probe sessions were conducted before the research session to determine if the child had acquired the skill, and therefore, if stimulus control had transferred. This was necessary because in the simultaneous prompting procedures the child was allowed the opportunity to respond independently, a situation that rendered it impossible to detect when stimulus control transferred from the prompt to the instruction.
Probe sessions consisted of three trials for each target. A target was considered mastered if the child responded correctly to all three presentations of the instruction for a specific target during one probe session. The target was then dropped from teaching and only the remaining targets were taught during the following teaching sessions.

Teaching Procedure

Simultaneous trials consisted of giving an instruction (e.g., "What is it?") after which the participant was immediately prompted (0-second delay) with the correct response, either physically or verbally, whichever was applicable, to respond correctly (e.g., "Say cat"). Reinforcement in the form of praise and tangible items (such as a preferred toy or food) was given following correct responses. If the participant did not respond correctly within five seconds after the prompt, the trial was terminated without reinforcement. A new trial began with the presentation of the instruction.

Our traditional constant prompt delay was modeled after Touchette's 1971 study, in which traditional constant prompt delay consisted of giving an instruction (e.g., "What is it?") and the participant immediately receiving a prompt (0-second delay), either physically or verbally, on the first trial to answer correctly (e.g., "Say dog"). The remaining four trials consisted of an instruction (e.g., "What is it?") but the participant receiving the opportunity to respond independently. If the participant correctly responded within five seconds of the instruction, praise and tangible items were delivered to reinforce the correct response. If there was no response or if the participant erred within five seconds of the instruction, a correction procedure was implemented by the experimenter providing a prompt for the participant to respond correctly (e.g., "Say dog"). If the participant responded correctly after the prompt, reinforcement was given. If there was no response or an incorrect response after receiving the prompt, a new trial began, with a five second delay before a prompt. This continued for the remainder of the trials for that session.

Our modified constant prompt delay procedure was based on procedures commonly used at our University Autism Program; this consisted of a traditional-type prompting procedure paired with a correction procedure. Modified constant prompt delay consisted of an instruction (e.g., "What is it?"), after which the participant was then immediately prompted (0-second delay), either physically or verbally, whichever was applicable, on the first trial to answer correctly (e.g., "Say duck"). The remaining four trials consisted of an instruction (e.g., "What is it?"), but the participant was given the opportunity to respond independently. If the participant gave a correct response within five seconds of the instruction, praise and tangible items were delivered. If there was no response or if the participant erred within five seconds of the instruction, a correction procedure was implemented by the experimenter returning to a 0-second prompt (e.g., "What is it?", "Say duck."). Following the prompt, the participant was given five seconds to respond correctly. If there was no response or an error occurred, the correction procedure was repeated. The correction procedure was repeated until the participant gave the correct response.

Results

The results for Nick's expressive adverbs are shown in Figure 1 and Table 1. In the traditional constant prompt condition Nick reached the criterion in eleven sessions (110 trials). In the same condition there were a total of 33 errors during the probes and 50 errors during teaching. In the simultaneous prompt condition Nick reached the criterion for expressive adverbs in thirteen sessions (115 trials). In the same condition there were a total of 22 errors during the probes and three errors during teaching.

The results for Brian's expressive adverbs are shown in Figure 2 and Table 2. In the modified constant prompt condition Brian reached the criterion in six sessions (70 trials). In the same condition there were a total of fourteen errors during the probes and 20 errors during teaching. In
the simultaneous prompt condition Brian reached the criterion for expressive adverbs in six sessions (75 trials). In the same condition there were a total of fifteen errors during the probes and no errors during teaching.

**Figure 1.** A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the traditional constant prompt delay procedures and the simultaneous procedures for Nick's expressive adverbs.

<table>
<thead>
<tr>
<th></th>
<th>Sessions</th>
<th>Trials</th>
<th>Errors During Probes</th>
<th>Errors During Teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant Traditional</td>
<td>11</td>
<td>110</td>
<td>33</td>
<td>50</td>
</tr>
<tr>
<td>Simultaneous</td>
<td>13</td>
<td>115</td>
<td>22</td>
<td>3</td>
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</tbody>
</table>

**Table 1.** Total Number to Criterion for Participant One (Nick), Expressive Adverbs.

**Figure 2.** A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the modified constant prompt delay procedures and the simultaneous procedures for Brian's expressive adverbs.

<table>
<thead>
<tr>
<th></th>
<th>Sessions</th>
<th>Trials</th>
<th>Errors During Probes</th>
<th>Errors During Teaching</th>
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</thead>
<tbody>
<tr>
<td>Constant Modified</td>
<td>6</td>
<td>70</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>Simultaneous</td>
<td>6</td>
<td>75</td>
<td>15</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 2.** Total Number to Criterion for Participant Two (Brian), Expressive Adverbs.

The results for Ellie's expressive addition are shown in Figure 3 and Table 3. In the modified constant prompt condition Ellie reached the criterion in fourteen sessions (70 trials). In the same condition there were a total of 28 errors during the probes and two errors during teaching.
In the simultaneous prompt condition Ellie reached the criterion for expressive addition in 21 sessions (105 trials). In the same condition there were a total of 51 errors during the probes and no errors during teaching. In phase two of Ellie’s expressive addition the traditional constant prompt condition resulted in Ellie’s reaching criterion in six sessions (30 trials). In the same condition there were a total of ten errors during the probes and four errors during teaching. In the simultaneous prompt condition, Ellie reached criterion in seven sessions (35 trials). In the same condition there were a total of nine errors during probes and no errors during teaching.

![Graph showing data](image)

**Figure 3.** A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the modified constant prompt delay procedures and the simultaneous procedures in phase one, and traditional constant prompt delay procedures and the simultaneous procedures in phase two for Ellie’s expressive addition.

<table>
<thead>
<tr>
<th></th>
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<td>Constant Modified</td>
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<td>2</td>
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<tr>
<td>Simultaneous</td>
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<tr>
<td>Constant Traditional (Phase Two)</td>
<td>6</td>
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<td>10</td>
<td>4</td>
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<tr>
<td>Simultaneous (Phase Two)</td>
<td>7</td>
<td>35</td>
<td>9</td>
<td>0</td>
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</tbody>
</table>

The results for Ellie’s expressive spelling are shown in Figure 4 and Table 4. In the traditional constant prompt condition Ellie reached the criterion in five sessions (55 trials). In the same condition there were a total of sixteen errors during the probes and nine errors during teaching. In the simultaneous prompt condition, Ellie reached the criterion for expressive spelling in six sessions (60 trials). In the same condition there were a total of four errors during the probes and one error during teaching. In phase two of Ellie’s expressive spelling, the modified constant prompt condition resulted in Ellie’s reaching criterion in two sessions (25 trials). In the same condition there were a total of four errors during the probes and ten errors during teaching. In the simultaneous prompt condition Ellie reached criterion in three sessions (35 trials). In the same condition there were a total of twelve errors during probes and no errors during teaching.

The results for Seth’s expressive addition are shown in Figure 5 and Table 5. In the traditional constant prompt condition Seth reached the criterion in eleven sessions (125 trials). In the same condition there were a total of 32 errors during the probes and 28 errors during teaching.
In the simultaneous prompt condition Seth reached the criterion for expressive addition in 21 sessions (215 trials). In the same condition there were a total of 54 errors during the probes and no errors during teaching. In phase two of Seth’s expressive addition, the modified constant prompt condition resulted in Seth’s reaching criterion in seven sessions (100 trials). In the same condition there were a total of 31 errors during the probes and 22 errors during teaching. In the simultaneous prompt condition, Seth reached criterion in nine sessions (110 trials). In the same condition there were a total of 24 errors during probes and no errors during teaching.

![Ellie - Expressive Spelling](image)

**Figure 4.** A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the traditional constant prompt delay procedures and the simultaneous procedures in phase one, and modified constant prompt delay procedures and the simultaneous procedures in phase two for Ellie’s expressive spelling.

<table>
<thead>
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<th></th>
<th>Sessions</th>
<th>Trials</th>
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<th>Errors During Teaching</th>
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<td>Simultaneous</td>
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<tr>
<td>Constant Modified (Phase Two)</td>
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<td>Simultaneous (Phase Two)</td>
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<td>12</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 4. Total Number to Criterion for Participant Three (Ellie), Expressive Spelling.**

![Seth - Expressive Addition](image)

**Figure 5.** A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the traditional constant prompt delay procedures and the simultaneous procedures in phase one, and modified constant prompt delay procedures and the simultaneous procedures in phase two for Seth’s expressive addition.
The results for Molly's receptive labeling are shown in Figure 6 and Table 6. In the traditional constant prompt condition Molly reached the criterion in seven sessions (90 trials). In the same condition there were a total of 21 errors during the probes and 31 errors during teaching. In the simultaneous prompt condition Molly reached the criterion for receptive labeling in fourteen sessions (105 trials). In the same condition there were a total of 29 errors during the probes and two errors during teaching.

| Table 5. Total Number to Criterion for Participant Four (Seth), Expressive Addition. |
|---------------------------------|--------|---------|----------------|----------------|
|                                 | Sessions | Trials  | Errors During Probes | Errors During Teaching |
| Constant Traditional           | 11      | 125     | 32              | 28              |
| Simultaneous                   | 21      | 215     | 54              | 0               |
| Constant Modified (Phase Two)  | 7       | 100     | 31              | 22              |
| Simultaneous (Phase Two)       | 9       | 110     | 24              | 0               |

![Molly - Receptive Labeling](image)

Figure 6. A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the traditional constant prompt delay procedures and the simultaneous procedures for Molly's receptive labeling.

| Table 6. Total Number to Criterion for Participant Five (Molly), Receptive Labeling. |
|---------------------------------|--------|---------|----------------|----------------|
|                                 | Sessions | Trials  | Errors During Probes | Errors During Teaching |
| Constant Traditional           | 7       | 90      | 21              | 31              |
| Simultaneous                   | 14      | 105     | 29              | 2               |

The results for Molly's receptive community helpers are shown in Figure 7 and Table 7. In the modified constant prompt condition Molly reached the criterion in eight sessions (105 trials). In the same condition there were a total of 20 errors during the probes and 40 errors during teaching. In the simultaneous prompt condition Molly reached the criterion for receptive community helpers in eleven sessions (165 trials). In the same condition there were a total of 33 errors during the probes and one error during teaching.

The results for Mark's selecting associated pictures are shown in Figure 8 and Table 8. In the modified constant prompt condition Mark reached the criterion in three sessions (25 trials). In the same condition there were a total of three errors during the probes and ten errors during teaching. In the simultaneous prompt condition Mark reached the criterion for selecting associated pictures in four sessions (40 trials). In the same condition there were a total of seven errors during the probes and no errors during teaching.
Figure 7. A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the modified constant prompt delay procedures and the simultaneous procedures for Molly's receptive community helpers.

| Table 7. Total Number to Criterion for Participant Five (Molly), Receptive Community Helpers. |
|---------------------------------|--------|----------------|-----------------|----------------|
|                                 | Sessions | Trials | Errors During Probes | Errors During Teaching |
| Constant Modified               | 8       | 105    | 20               | 40               |
| Simultaneous                    | 11      | 165    | 33               | 1                |

Figure 8. A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the modified constant prompt delay procedures and the simultaneous procedures for Mark's selecting associated pictures.

| Table 8. Total Number to Criterion for Participant Six (Mark), Selecting Associated Pictures. |
|---------------------------------|--------|----------------|-----------------|----------------|
|                                 | Sessions | Trials | Errors During Probes | Errors During Teaching |
| Constant Modified               | 3       | 25     | 3                | 10               |
| Simultaneous                    | 4       | 40     | 7                | 0                |

The results for Mark's expressive before and after are shown in Figure 9 and Table 9. In the traditional constant prompt condition Mark reached the criterion in five sessions (65 trials). In the same condition there were a total of 24 errors during the probes and ten errors during teaching. In the simultaneous prompt condition Mark reached the criterion for expressive before and after in four sessions (35 trials). In the same condition there were a total of nine errors during the probes and no errors during teaching.

The results for Mark's expressive opposites are shown in Figure 10 and Table 10. In the traditional constant prompt condition Mark reached the criterion in eight sessions (85 trials). In
the same condition there were a total of 25 errors during the probes and 23 errors during teaching. In the simultaneous prompt condition Mark reached the criterion for expressive opposites in four sessions (45 trials). In the same condition there were a total of thirteen errors during the probes and one error during teaching.

![Mark - Expressive Before/After](image)

**Figure 9.** A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the traditional constant prompt delay procedures and the simultaneous procedures for Mark's expressive before and after.

<table>
<thead>
<tr>
<th></th>
<th>Sessions</th>
<th>Trials</th>
<th>Errors During Probes</th>
<th>Errors During Teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant Traditional</td>
<td>5</td>
<td>65</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>Simultaneous</td>
<td>4</td>
<td>35</td>
<td>9</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Sessions</th>
<th>Trials</th>
<th>Errors During Probes</th>
<th>Errors During Teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant Traditional</td>
<td>8</td>
<td>85</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>Simultaneous</td>
<td>4</td>
<td>45</td>
<td>13</td>
<td>1</td>
</tr>
</tbody>
</table>

![Mark - Expressive Opposites](image)

**Figure 10.** A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the traditional constant prompt delay procedures and the simultaneous procedures for Mark's expressive opposites.

The results for Derek's object imitation are shown in Figure 11 and Table 11. In the modified constant prompt condition Derek reached the criterion in six sessions (40 trials). In the same condition there were a total of nine errors during the probes and sixteen errors during teaching.
In the simultaneous prompt condition Derek reached the criterion for object imitation in three sessions (30 trials). In the same condition there were a total of five errors during the probes and three errors during teaching.

![Derek - Object Imitation](image)

**Figure 11.** A bar graph comparing the total number to criterion of sessions, trials, errors during probes, and errors during teaching between the modified constant prompt delay procedures and the simultaneous procedures for Derek's object imitation.

<table>
<thead>
<tr>
<th></th>
<th>Sessions</th>
<th>Trials</th>
<th>Errors During Probes</th>
<th>Errors During Teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant Modified</td>
<td>6</td>
<td>40</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Simultaneous</td>
<td>3</td>
<td>30</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table 11. Total Number to Criterion for Participant Seven (Derek), Object Imitation.**

**Discussion**

Both procedures were found effective in teaching acquisition skills to children with autism. This finding is consistent with past research, such as Morton & Flynt (1997) and Tekin & Kircaali-Iftar (2002). However, these findings are not consistent with past research in terms of which procedure was found to be more efficient. Riesen, McDonnell, Johnson (2003) and Tekin & Kircaali-Iftar (2002) found that the simultaneous procedures resulted in the participants learning the skills in less time. The results from our study indicate that neither of the constant prompt delay procedures were more efficient than the simultaneous prompting procedure in seven of the eleven programs. Three of the eleven programs had more efficient acquisition with the simultaneous procedures and in one program there were no differences. In terms of errors, simultaneous prompting resulted in fewer teaching errors in all eleven programs and fewer probe errors in five of the eleven programs. These results indicate that constant prompt delay tends to take fewer trials and sessions, but results in more errors than the simultaneous.

The three programs that included a second phase constant prompt delay, which compared the constant prompt delay procedure that had not yet been used with the simultaneous prompting, resulted in fewer trials and sessions for all three programs. Simultaneous prompting also resulted in fewer teaching errors for all three programs and in fewer errors during probes for two of the three programs. Three programs included a second phase, and it was quite evident that practice effects were taking place, since one of the procedures had already been used. Therefore, the remaining programs were only taught in the first phase and not in the second.

Some limitations to this study are that there were no generalization or maintenance data collected for any of the programs, and that the two constant prompt delay procedures were never compared to each other, but only to the simultaneous prompting procedure. Future research should investigate and determine whether one procedure results in better generalization or maintenance.
than the other. Another option would be to compare the constant prompt delay procedures to see if the difference in pairing the correction procedure with the instruction makes the modified constant prompt delay procedure more effective and/or efficient than the traditional constant prompt delay. Future research should also investigate the possibility of combining the constant prompt delay and the simultaneous procedures to develop a method that would result in more efficient learning with fewer errors during acquisition.

The results of this research indicate both procedures are effective in teaching new skills to children with autism. Since both are effective, the prompting method used should be selected according to the specific needs of the individual child. It seems that the constant prompt delay procedures might be the best method to use if the main interest is speed of acquisition, since this procedure, in general, resulted in fewer trials and sessions. If the child is one who engages in a lot of problem behaviors as a function of frustration over incorrect responses or correction procedures, simultaneous prompting might be the better choice because it typically results in fewer errors throughout the session.

There is no clear indication from this study that one procedure is completely superior to the other; however, it does provide further evidence that both procedures can be used to teach new skills and can also be used effectively for children with autism for a wide variety of skills. This study also indicates choice of prompting method should take into consideration the needs of the specific child and program being taught.

References


**Acknowledgments**

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Realizing Keplerian Orbits as Geodesics on a Surface of Revolution

by

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Department of Mathematics

1 Background
It is well known that in Newtonian physics, the gravitational trajectories in a central gravitational field are conic sections with one focus at the central mass. This is Kepler's First Law. We consider those gravitational trajectories that lie in a fixed plane $P$ (perhaps thought of as an ecliptic plane), and investigate this question:

*To what extent can $P$ be embedded as a surface of revolution $S$ inside an abstract three-dimensional Euclidean space $E$ in such a way that gravitational trajectories are mapped to geodesics on $S \subset E$?*

We use polar coordinates $(\Phi, R)$ for $P$, and recall [1] that the differential equation defining the gravitational trajectories is

$$\left( \frac{d\eta}{d\phi} \right)^2 = \frac{h}{J^2} + \frac{2M}{J^2} \eta - \eta^2$$

(1)

where $\eta = 1/R$, $M$ is the mass of the object setting up the gravitational field, $J$ is the magnitude of the angular momentum of a particle as it orbits around the central mass, and $h$ is a parameter related to the eccentricity of the orbit. In fact

$$e^2 = 1 + \frac{hJ^2}{M}$$

(2)

where $e$ is the eccentricity. The general solution to this differential equation is

$$\eta = \frac{M}{J^2} (1 + e \cos(\phi - \phi_0)).$$

(3)

This is the polar equation of a conic with focus at the origin and eccentricity $e$. The directrix of the conic is the line $x = J^2/(Me)$ rotated by an angle $\Phi_0$.

*Figure 1:* Conics in the family $F(\epsilon, \Phi_0)$ with $\Phi_0 = 0$. The ellipses and the left branches of the hyperbolae correspond to $R > 0$, while the right branches correspond to $R < 0$. Note the common *lotus rectum*, which is a diameter of the circle $R = f/M$. Other members of the family are obtained by rotating these conics around the focus, which is situated at the origin.
For a surface we expect in general that the trajectories of its geodesics will depend upon two parameters. For example, the generic line in the plane can be parameterized by slope and y-intercept, and a great-circle on the sphere can be parameterized by the latitude and longitude of the "pole" of the great-circle. To make our problem well-posed, we will regard not only $M$ but also $F$ as a fixed parameter, and thus we will view the solution (3) as depending on the two parameters $\Phi_0$ and $\epsilon$ (or $b$). The resulting two-parameter family of solutions $F = F(\epsilon, \Phi_0)$ is a subfamily of a family of confocal conics in $P$. To give a geometrical description of the family of conics, one needs recall that the \textit{latus rectum} of a conic is the chord through its focus and parallel to its directrix. Half the length of this chord is called the \textit{semilatus rectum}, and in terms of (3), the \textit{semilatus rectum} is equal to $F/M$. Thus $F(\epsilon, \Phi_0)$ is the subfamily of confocal conics with fixed semilatus rectum $F/M$. See Figure 1.

\section{Geometry of a Surface of Revolution in $E$}

We may endow our three-dimensional Euclidean space $E$ with coordinates $(x, y, z)$ with a flat metric $ds$ in one of two ways:

$$ds^2 = dx^2 + dy^2 + dz^2$$

$$ds^2 = dx^2 + dy^2 - dz^2.$$ 

In the former case, the inner product of two vectors $v$ and $w$ is

$$\langle v, w \rangle = v_1 w_1 + v_2 w_2 + v_3 w_3$$

while in the latter case it is

$$\langle v, w \rangle = v_1 w_1 + v_2 w_2 - v_3 w_3.$$ 

We shall refer to $E$ as $E^{3,0}$ or $E^{2,1}$ depending upon which metric we choose to impose upon $E$.

The space $E^{3,0}$ is most familiar to our intuition. Sets of points $S$, for which $\langle v, v \rangle = c$ are round spheres, and the constant $c$ must, of course, be nonnegative. The space $E^{2,1}$ is less familiar, although it is reminiscent of Minkowski space. In this case the constant $c$ can be negative, and we find that $S$ is a hyperboloid of one-sheet, a cone, or a hyperboloid of two-sheets depending upon whether $c > 0$, $c = 0$ or $c < 0$. We shall find that we can embed $P$ into $E$ when $E = E^{2,1}$ using the hyperboloids corresponding to $c = \pm F/M$.

The differential geometry of a surface of revolution $S \subset E$ is determined by its so-called \textit{first fundamental form} $ds^2$, which in turn is determined by restricting $d^2$ from the ambient space $E$. If $(\Phi, \eta)$ are coordinates on $P$ so that we can describe the map $P \rightarrow E$ by

$$X(\phi, \eta) = (x(\phi, \eta), y(\phi, \eta), z(\eta))$$

$$= (\alpha(\eta) \cos(\phi), \alpha(\eta) \sin(\phi), z(\eta))$$

for some functions $\alpha = \alpha(\eta)$ and $z = z(\eta)$, then

$$ds^2 = E(\eta)d\phi^2 + G(\eta)d\eta^2$$

where

$$E = \left\langle \frac{\partial X}{\partial \phi}, \frac{\partial X}{\partial \phi} \right\rangle, \quad G = \left\langle \frac{\partial X}{\partial \eta}, \frac{\partial X}{\partial \eta} \right\rangle.$$ 

Note that in our $(\Phi, \eta)$ coordinate system for $S$, $\left\langle \frac{\partial X}{\partial \eta}, \frac{\partial X}{\partial \phi} \right\rangle = 0$

and $E$ and $G$ depend only on $\eta$. Such a coordinate system is said to be an $\eta$-Clairaut patch.
3 Geodesics on S
In this section we follow closely the development in [2]. Let \( \gamma = \gamma(\tau) \) be a geodesic on \( S \). Using our parameterization (4) for \( S \), we can represent \( \gamma \) by \( \gamma(\tau) = (a(\eta)\cos(\Phi), a(\eta)\sin(\Phi), z(\eta)) \) where \( \eta = \eta(\tau) \) and \( \Phi = \Phi(\tau) \). The geodesic condition is equivalent to the tangential component of the acceleration being zero, and thus \( \langle \gamma'(\tau), \gamma'(\tau) \rangle \) is constant. We will assume that the value of this constant is \( \sigma = \pm 1 \). Of course \( \sigma = +1 \) if \( \gamma \) is a curve in \( E^{3,0} \), but we need to allow for the possibility that \( \sigma = -1 \) when \( \gamma \) is a curve in \( E^{2,1} \). It is well known that the equations for a geodesic curve \( \gamma(\tau) \) in such a situation reduce to

\[
\phi'' + \frac{E\phi'}{E} \phi' = 0
\]

(6)

\[
\eta'' - \frac{E\eta}{2G} + \frac{G\eta}{2G^2} \eta^2 = 0
\]

(7)

where \( \Phi' \) and \( \eta' \) denote differentiation with respect to \( \tau \). Now

\[
(E\phi')' = E\phi' + E\phi'' = (E\eta')' + E\phi'(\phi' + E\phi'') = 0
\]

by using \( E = 0 \) and (7). Therefore,

\[
E\phi' = c.
\]

(8)

Solving

\[
\sigma = \langle \gamma', \gamma' \rangle = E\phi'^2 + G\eta'^2 = \frac{c^2}{E} + G\eta'^2
\]

for \( \eta'^2 \), we get

\[
\eta'^2 = \frac{\sigma E - c^2}{EG}.
\]

(9)

Thus, if we change the parameter of the geodesic \( \gamma \) from \( \tau \) to \( \Phi \), then we are led to the differential equation

\[
\left( \frac{d\eta}{d\phi} \right)^2 = \frac{\sigma E^2}{E^2G} - \frac{E}{G}
\]

(10)

where \( c \) is a constant. This follows from (8), (9) and the fact that

\[
\frac{d\eta}{d\phi} = \frac{d\eta/d\tau}{d\phi/d\tau}.
\]

4 Determining the Surface \( S \)
In order to determine the first fundamental form of \( S \), we must determine the functions \( E \) and \( G \). To do this, we compare (1) and (10). This leads us to the three equations

\[
\frac{E^2}{G} = \lambda = \text{constant}
\]

\[
\frac{h}{\tau^2} = \frac{\sigma \lambda}{c^2}
\]

\[
-\frac{E}{G} = \frac{2M\eta}{\tau^2} - \eta^2
\]

(11)

This determines \( E \) and \( G \):

\[
E(\eta) = \frac{J^2 \lambda}{J^2 \eta^2 - 2M\eta}
\]

\[
G(\eta) = \frac{J^2 \lambda}{(J^2 \eta^2 - 2M\eta)^2}
\]

(12)
Now in order to determine $S$, we determine the functions $\alpha$ and $z$ in (4) by using (5). We find

$$\alpha(\eta) = \sqrt{\frac{J^2 \lambda}{J^2 \eta^2 - 2M \eta}}$$  \hspace{1cm} (13)

$$z_{30}(\eta) = \int \sqrt{G(\eta) - \alpha'(\eta)^2} \, d\eta$$  \hspace{1cm} (14)

$$z_{21}(\eta) = \int \sqrt{\alpha'(\eta)^2 - G(\eta)} \, d\eta$$  \hspace{1cm} (15)

where we use $z_{30}$ or $z_{21}$ depending on whether $S$ is in $E^{3,0}$ or $E^{2,1}$.

In order for real solutions $\alpha(\eta)$ and $z(\eta)$ to exist, we must have $E(\eta) > 0$ and $G(\eta) - \alpha'(\eta)^2 > 0$ (for $z_{30}$) or $\alpha'(\eta)^2 - G(\eta) > 0$ (for $z_{21}$). Since

$$G(\eta) - \alpha'(\eta)^2 = \frac{\lambda J^2 M^2}{\eta^3 (2M - J^2 \eta)^{3}},$$  \hspace{1cm} (16)

we find that no solutions exist for the case of $E^{3,0}$ but that solutions exist for $E^{2,1}$. In fact

$$z_{21}(\eta) = -\frac{J (J^2 \eta - M)(J^2 \eta - 2M)}{M} \sqrt{\frac{\lambda}{\eta (J^2 \eta - 2M)^3}}$$  \hspace{1cm} (17)

It is straightforward to verify that

$$\alpha(\eta)^2 - z_{21}(\eta)^2 = -\frac{\lambda J^4}{M^2}$$  \hspace{1cm} (18)

Thus $S \subset E^{2,1}$ is a “sphere” for the inner product on $E^{2,1}$. We recognize $S$ as a hyperboloid of two-sheets (if $\lambda > 0$) or one-sheet (if $\lambda < 0$). Furthermore, note that $S$ is a homogeneous isotropic space—it has constant curvature and the isometry group $O(2, 1)$ of $E^{2,1}$ acts on $S$ and takes geodesics to geodesics. Just as geodesics on the round sphere in $E^{3,0}$ are great circles which can be realized as sections of the sphere by planes passing through the origin, geodesics on $S$ are obtained by intersecting $S$ with planes in $E^{2,1}$ passing through the origin. In fact, by a direct calculation, one can verify that if $\eta(\Phi), z_{21}(\eta)$ and $X(\Phi, \eta) = \alpha(\eta) \cos(\Phi)$ are given by equations (3), (13) and (15), then

$$eX(\phi, \eta(\phi)) + z_{21}(\eta(\phi)) = 0 \text{ if } \phi_0 = 0.$$  \hspace{1cm} (19)

Thus the geodesic on $S$ corresponding to the gravitation trajectory of equation (3) is in the plane $ex + z = 0$ when $\Phi_0 = 0$.

**Figure 2:** The extended surface $S$ consisting of hyperboloids of one and two sheets in $E^{2,1}$. Region I corresponds to $J^2/2M < R$, Region II corresponds to $0 < R < J^2/2M$ and Region III corresponds to $R < 0$. See Table (1).
5 The Correspondence Between P and S
We define \( S \) to be the surface defined by equation (18) for \( \lambda = \pm 1 \). Thus \( S \) consists of a hyperboloid of one-sheet and a hyperboloid of two-sheets. Recall that \( F = F(e, \Phi_0) \) is the two-parameter subfamily of conics in \( P \) with focus at the origin and fixed semilatus rectum \( J/IM \). We find that elliptical trajectories in \( F \) map to geodesics on the hyperboloid of one-sheet. See Figure (3). Furthermore, we find that the branch of a hyperbolic trajectory in \( F \) with \( R > 0 \) maps partially to the hyperboloid of one-sheet and partially to the lower-branch of the hyperboloid of two sheets. See Figure (4). Branches of hyperbolic trajectories with \( R < 0 \) correspond to geodesics on the upper sheet of the hyperboloid of two-sheets. These results and similar correspondences can be seen in Table 1.

<table>
<thead>
<tr>
<th>Range for ( R )</th>
<th>( \lambda )</th>
<th>( S )</th>
<th>( \sigma = \langle \gamma', \gamma' \rangle )</th>
<th>( e )</th>
<th>Important Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R &gt; J/IM(2M) )</td>
<td>-1</td>
<td>hyperboloid of one sheet</td>
<td>positive or negative</td>
<td>( e &lt; 1 ) (ellipses) or ( e &gt; 1 ) (hyperbolae)</td>
<td>( \lim_{R \to -\frac{J^2}{IM}} \gamma_{21} = -\infty )</td>
</tr>
<tr>
<td>( 0 &lt; R &lt; J/IM(2M) )</td>
<td>+1</td>
<td>hyperboloid of two sheets (lower sheet where ( z_{21} &lt; 0 ))</td>
<td>positive</td>
<td>( e &gt; 1 ) (hyperbolae)</td>
<td>( \lim_{R \to 0^+} \gamma_{21} = \frac{J^2}{IM} ) ( \lim_{R \to 0^-} \gamma_{21} = -\infty )</td>
</tr>
<tr>
<td>( R &lt; 0 )</td>
<td>+1</td>
<td>hyperboloid of two sheets (upper sheet where ( z_{21} &gt; 0 ))</td>
<td>positive</td>
<td>( e &gt; 1 ) (hyperbolae)</td>
<td>( \lim_{R \to 0^-} \gamma_{21} = \frac{J^2}{IM} ) ( \lim_{R \to -\infty} \gamma_{21} = \infty )</td>
</tr>
</tbody>
</table>

Figure 3: A elliptical Keplerian orbit in \( F \) and the corresponding geodesic on \( S \). The circles on the right are the circles \( R = J/IM(2M) \) and \( R = J/IM \). The latter corresponds to the narrow waist of \( S \), which is obviously a geodesic.
Note that the meridians of $S$ (intersection of $S$ by planes in $\mathbb{E}^3$ containing the $z$-axis) are geodesics of $S$. We should understand how these geodesics correspond to curves in the family $F$. To do this, we rewrite the polar equation (3) of a conic in $F$ with $\Phi_0 = 0$ in rectangular coordinates. We obtain
\[
\left(x + \frac{eJ^2}{M(e^2 - 1)^2}\right)^2 - \frac{y^2}{e^2 - 1} = -\frac{J^4}{M^2(e^2 - 1)^2} + \frac{e^2 J^2}{M^2(e^2 - 1)^2}
\] (20)
Notice that as $e \to \infty$, we have hyperbolas tending to the “repeated” vertical line $x^2 = 0$. We regard this repeated line as a member of $F$. One line is the limiting position of right branches ($R < 0$) of hyperbolas, and maps to a meridian of the upper sheet of the hyperbola of two-sheets. The other line maps to a meridian on the hyperboloid of one-sheet and a meridian of the lower branch of the hyperboloid of two-sheets. Specifically, the segment from $(0,-J^2(2M))$ to $(0,J^2(2M))$ maps to the lower sheet, while the two remaining rays map to the hyperboloid of one-sheet.

References
Offensive Gas Technology: Its Effect on British Policy Changes in the Great War

by

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The assassination of Archduke Franz Ferdinand, heir to the Austro-Hungarian Empire, on June 28, 1914, gave the Austrians reason to take hostile action toward Serbia. In order to turn the war to their favor, the Austro-Hungarian government sought, and was granted, the support of Germany.¹ On July 19, the Austro-Hungarian government drew up an ultimatum for Serbia, calling for a condemnation of further anti-Austrian propaganda and support of terrorists' activities. The Austrians also called for the participation of Austrian officials in the Serbian judicial process of those discovered circulating anti-Austrian propaganda.² However, on the evening of July 23, the Austro-Hungarians delivered their ultimatum to Serbia, demanding an answer to the ultimatum within 48 hours.³

On July 25, Serbia began to mobilize its military, while at the same time sending a reply to Austro-Hungary, stating that the Serbs would comply with Austrian demands. However, they wanted the Austrians' demand to participate in the judicial process to be submitted to the mediation of the International Tribunal at The Hague. The Austro-Hungarians were not pleased with the Serbian reply, and on July 28, 1914, they declared war on Serbia. In a matter of a week the five European Empires (France, Germany, Great Britain, Russia, and Austro-Hungary) were at war with each other. On August 1, Germany declared war on Russia. Because of a protection treaty signed between Russia and France, Germany also declared war on France on August 3.⁴ The only empire left to join was Great Britain, which on August 4 entered the fighting when Germany invaded neutral Belgium, which was under the protection of the 1839 Treaty of London.⁵ This was the beginning of the Great War that pitted the Allies (Great Britain supported by dominion troops from Canada, France, Russia and Italy, which joined in April 1915) versus the Central Powers (Germany, Bulgaria, Austria-Hungary and the Ottoman Empire).

The War on the Western Front

When Germany invaded Belgium on August 4, the Germans first hit the fortified town of Liège, which they took in a matter of days. The Belgian army was eventually forced north to Antwerp where they could consolidate their forces and gain the protection of a series of fortresses surrounding the city [Map 1]. The British attempted to halt the German advance through Belgium and into France at Mons on August 23-24. The British Expeditionary Force (BEF) only numbered four divisions compared to Germany's six.⁶ The British, though outnumbered, inflicted heavy casualties on the German forces.⁷ Despite their apparent victory, the BEF received orders to retreat, bringing both the French and British forces to the outskirts of Paris.⁸ The British forces, in late August 1914, formed a barrier between Paris and the German army at the river Marne.⁹

During the Battle of the Marne, from September 6 to 10, the French and the British combined forces pressed the German armies, under the direction of General Moltke, to withdraw to the area near the River Aisne. To solidify the German lines along the river, Moltke ordered his
forces to dig trenches in order to make their line defensible. It was this order that initiated trench warfare and the stagnation of the lines. At this point in the conflict, General Moltke was dismissed from command and replaced by Prussian war minister, Erich von Falkenhayn. The Allies and the Germans, in their attempts to out-maneuver each other and gain the advantage, headed north to Flanders [Map 2].10 With every attempt by the Germans to circumnavigate the French forces, the French sent in new forces, further solidifying the lines into trench warfare. As German forces worked their way north in their "race to the sea," they eventually met with the remainder of the Belgian forces and the British Expeditionary Force at the Belgian town of Ypres.11 The battle that ensued on October 18, 1914, called the First Battle of Ypres, caused 250,000 casualties among the Germans, French, and the British, but no breakthrough.

Map 1. Invasion of France. (Source: Willmott, p. 43.)

The Second Battle of Ypres

In late 1914 the Germans, looking for an effective way to break the stalemate along the Western Front, turned to the use of chemical weapons. Despite authorization from German Chief of General Staff, General Erich von Falkenhayn, who had command of the troops along the Western Front, many of the German army commanders refused to use poisonous gas weapons in their battle plans.12 Most of the commanders feared that the use of poisonous weapons would break the international agreements set by the Hague Conventions of 1899 and 1907, which forbade the use
of projectiles filled with asphyxiating gas.\textsuperscript{13} If the commanders broke the agreements, they feared the Allies would seek retribution on the German army with a comparable Allied attack. Only the commander of the Fourth German Army, Duke Albrecht of Wurttemberg, who faced the Allied salient, a projection of forces into the enemy-held territory around Ypres, was willing to use gas. The Supreme German Command saw the use of gas as “unchivalrous,” yet they were optimistic that new gas weapons could give them a great victory, starting with the capture of Ypres.\textsuperscript{14}


The Germans began to install a large number of cylinders filled with 150 tons of chlorine gas along 4.5 miles of the Ypres salient on April 5, 1915.\textsuperscript{15} Once the infantry completed the installation of nearly 6,000 cylinders and the weather was favorable, the German special gas infantry released the 150 tons of gas onto the Canadian and French lines, beginning the Second Battle of Ypres. The French Algerian infantry was the first to encounter the chlorine gas cloud. The Canadians, alarmed at what happened, and waiting for a proper German attack, manned their firing step and began shooting into the cloud to prevent the Germans from taking the trench.\textsuperscript{16} The men in the trenches were unprepared for a chemical assault, and many of the British and Canadian forces were ordered to urinate on a handkerchief and hold it against their mouths in order to provide some protection against the gas.\textsuperscript{17}

The German use of gas brought what had not existed since the start of the war—an return of mobility to the lines. The German commanders were astonished that the gas was so effective. However, most of the German infantry lacked proper protection from gas.\textsuperscript{18} The Germans also failed to allot for reserve infantry to carry on the offensive. These problems of improper planning prevented the Germans from filling a two-mile gap left in the Allied line by the retreating French forces. Instead the British infantry was able to fill the gap.\textsuperscript{19} The use of gas by the Germans further enhanced the Allied notion that the Germans were uncivilized and pressed the British to respond
in kind for fear of losing the technological edge and the morale of their infantry. Some British officers felt that gas would bring about a new evolution in warfare by becoming an additional standard for the British army. However, the majority of British generals failed to take into account the drawbacks of the primitive deployment methods of gas weapons and the difficulties imposed on their use by wind and ground conditions. This paper discusses two battles, the Battle of Loos and the Battle of Arras, in which the British use of gas played a major role in determining the outcome of the battles. It also addresses the evolution of offensive gas technology and the changes in policies for using gas that occurred prior each of these battles.

Preparations for Retaliation

In the chaotic days after the Second Battle of Ypres, the British Secretary of State for War, Lord Kitchener, along with others in the War Office, began to organize and design plans for retaliation. The first step in this process was to create a new branch of the military, which would become known as the British Special Companies. This group was to conduct offensive gas operations and instruct the infantry in anti-gas protection. Major Charles Foulkes (Royal Engineer) was chosen by the War Office and General French, Commander of the BEF, assumed command of the new group.

In choosing Foulkes, Kitchener and the War Office relied primarily on his previous experience and distinguished service in the British army, starting with the Boer War in 1899. The fact that Foulkes had no previous knowledge of chemicals and their properties did not concern those in the War Office or General French. Foulkes, in order to compensate for his lack of knowledge and understanding of gas warfare, attended chemical experiments and interviewed chemical experts in Paris and London. After gaining some understanding of chemical warfare, he began pushing for the use of chlorine gas cylinders which would spray the gas across a field through parapet pipes, each weighing 160 pounds, as the only way to employ gas. Foulkes determined that he would need around 640 men to carry out any gas operation using the gas-filled cylinders.

Long before Foulkes started making demands for manpower, the War Office asked the universities to make lists of those students most suitable for the new British Special Companies. The army also searched the lists of those who had already enlisted in the hopes of finding men with chemical knowledge. This initial group of university educated and enlisted men formed the Special Party which eventually expanded into the core of Special Companies. The official formation of the Special Companies occurred on June 16, 1915, when the War Office approved two companies totaling 670 men. After some brief military training the Companies were sent to France, just after the Second Battle of Ypres, to become anti-gas instructors and quell the fear of German gas use throughout the BEF. By July of 1915 the group, along with new recruits now numbering around 400 men, was sent to Helfaut, France to receive more detailed training in chemical warfare. From July until early September 1915, the men of the Special Brigade practiced for the planned retaliation at Helfaut against the Germans, originally scheduled for September 15, 1915. The group's training and preparation consisted of marching, revolver drill, lectures, or hands-on training with empty cylinders. The lectures provided them with information important to executing a gas cylinder operation, such as determining wind direction and velocity, chemical properties, judging distances and protective practices. On September 9, the War Office approved the addition of another company to the Special Brigade. This company was comprised of volunteers from the Artists' Rifles and from two regiments from the London Rifle Brigade. The longest period of training any soldier in these groups received was six weeks. When the men finished their training on September 4, 1915, they were transported to the British lines surrounding Loos.
Battle of Loos: September 25, 1915

The Battle of Loos was a joint French and British offensive designed by Joseph Joffre, the French Commander-and-Chief, in July 1915. The attack was to be a two pronged offensive that would overwhelm the German forces by causing them confusion in regards to where to place their reserves. The British were hesitant to commit to the battle because they were concerned about Germany’s strong and well organized defenses. German artillery held higher ground, allowing them to watch and fire at the British infantry as it advanced across “no man’s land.” General Sir Douglas Haig, the second in command of the BEF, was more concerned about having enough equipment and material to carry out such a large operation. Already, it was planned that gas should be used to help supplement the shortage of artillery shells and ammunition. The use of gas in a supportive role went against the knowledge gained by the British at the Second Battle of Ypres. During this time, gas warfare had been used to instill panic in the enemy infantry, and to create an opportunity for the British to advance.

By the beginning of September Haig had changed his mind and gave his support for the Loos offensive. As the date for the initiation of the offensive drew near, intelligence reports changed, claiming that the Germans no longer had large reserves. On September 18, the general headquarters (GHQ) laid out the battle objectives: to break the German front, to prevent the German forces from reestablishing their line, and to defeat the divided German forces. They also wanted the gas to reach the German reserves, making them weak and easy to defeat. In order for this to happen, gas released from cylinders in the British front line needed the wind to carry it through a number of entrenched German lines.

After watching a number of gas practice operations the summer before, many of the generals, especially Haig, had great confidence in the effectiveness of gas. As the day of the battle approached, however, problems began to appear. One was a shortage of chlorine gas cylinders. Haig requested 7,000 gas cylinders from the Ministry of Munitions, but by the start of the battle only 5,000 had been received. Of these, 2,566 had arrived just before the start of the battle. Once all the cylinders had been unloaded from their transports, the men began the arduous task of emplacing the 5,000 cylinders, each weighing 160 pounds, into a parapet at a depth of four feet at intervals of 25 yards [Figures 1 and 2]. In all, 400 emplacements were set, each containing eleven to thirteen cylinders. The task of hauling and installing the cylinders was performed by 400 men from the Special Brigade and an additional 4,000 men from the front line.

Figure 1. Gas cylinder assembly after the Battle of Loos. This image shows how the gas cylinders were set up after the Battle of Loos. The major difference is that this later way to assemble the cylinders used a rubber hose and a three-way valve. (Source: Richter, p. 70.)
The Special Companies

On September 24, as the gas cylinders were put in place, Foulkes and Haig watched the weather reports. The Special Companies placed 40 officers throughout the attack area who were ordered to report the wind velocity and direction to Foulkes and the chief meteorologist, Ernest Gold. In addition, the commanders also received reports from weather stations in England, Spain, and France. Throughout September 24, the wind and weather were unfavorable for gas operations, but the chief meteorologist had hoped that a low front from Spain would cause the wind to shift slightly, making conditions more favorable. By 9 p.m., conditions had improved enough to permit Haig to send a message at 9:45 p.m. approving the use of gas. On September 25 the time to release the gas cylinders, or zero hour, was communicated to the members of the Special Brigade between 3 and 4 a.m.

At daybreak on September 25, the wind once again began to shift and became unfavorable, especially toward the north near La Bassée Canal. With all the cylinders in place, and questions about the wind direction beginning to form, a stray German mortar shell fell on one of the cylinder emplacements. The cylinder ruptured, soaking the trench with liquid chlorine. Despite their concerns about wind direction, the BEF commanders decided to commence the general use of gas. At zero hour, 5:50 a.m., the Special Companies opened the cylinders all along the seven-mile front [Figure 3].

Figure 2. Deployment of a cylinder. (Source: Richter, p. 72.)

Figure 3. The principle of using a gas cloud. (Source: Richter, p. 72.)
Once the battle started, problems with the cylinders began to develop. The muddy and cramped environment of the trenches, along with the drop in temperature caused by the release of pressurized chlorine, hindered the release of gas upon the German trenches. After the men of the Special Companies had emptied one cylinder, they had to remove the parapet pipe and rejoin it to the next cylinder. This action allowed mud from the trench to get into the screw heads of the pipes, preventing a tight connection. The loose connection allowed gas to leak into the trench. Furthermore, when the cylinders were changed, the pipes released what was left of the gas from the previous cylinder back into the trench. The constant cold that the pipes and connecting equipment were exposed to made some pipes burst and nuts warp, which made it difficult to connect the cylinders; this filled the British trench with even more gas.

Map 3. The Battle of Loos. (Richter, p. 65. Note that this map has been heavily modified from the original.)

General Haig was optimistic that the Battle of Loos could be a success with the use of gas despite a lack of heavy artillery, ammunition, and men. The offensive bombardment of Loos from the British front began on September 21 and lasted until an hour before the gas assault. The artillery was to prepare for the assault on the German front line by destroying the barbed wire placed throughout the German line. The British, however, had no artillery capable of reaching the second German line and were depending on the gas to reach this goal, as well as to help neutralize the Germans.
remaining in the first and reserve lines. The orders given to the men were intricate and stretched the men to their limits. [See Tables 1 and 2.]

<table>
<thead>
<tr>
<th>Units</th>
<th>Objectives</th>
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<tr>
<td>7th and 9th</td>
<td>Punch a hole in the North end of German lines.</td>
</tr>
<tr>
<td>2nd Division</td>
<td>Capture German second line from North Hulluch, St Elie and Haisnes.</td>
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<td></td>
<td>Continue onto Haute Duele Canal.</td>
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<td>Capture enough ground to protect the northern flank but not to advance past the 7th and 9th Divisions.</td>
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<thead>
<tr>
<th>Units</th>
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<tr>
<td>1st and 15th</td>
<td>Capture the German second line of trenches.</td>
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<tr>
<td>15th Division</td>
<td>Advance to the outskirts of Loos.</td>
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<tr>
<td>1st Division</td>
<td>Take Loos.</td>
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<td></td>
<td>Take Hill 70.</td>
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<td></td>
<td>Take Cite St. Auguste.</td>
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<tr>
<td>47th Division</td>
<td>Form a defensive flank southwards, covering 1st and 15th Divisions.</td>
</tr>
<tr>
<td></td>
<td>Take the Double Cassier and Enclosure south of Loos.</td>
</tr>
<tr>
<td></td>
<td>Take the German Second line.</td>
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**Gas, the “Boomerang Ally”**

Gas had a variety of effects on the two major corps, the 1st Corps commanded by General Sir Hubert Gough and the 4th Corps commanded by Sir Henry Rawlinson. In some instances gas use benefited the outcome of the battle, yet in other cases it provided disastrous effects. This section first discusses how gas affected the 2nd and 1st Divisions, and then how the 7th and 47th Divisions were hindered in obtaining their objectives [Map 4]. The wind around the 2nd Division was blowing SSW at a light but varying strength. The gas released by the British Special Companies traveled toward the northeast, blowing back into the small salient, and collecting in British trenches near La Bassée Canal causing the 2nd Division’s southernmost brigade, the 5th, to be engulfed in gas. The density of gas in the British trench was thick and those wearing protective “P” anti-gas helmets, which only provided protection for low concentrations of chlorine gas, became casualties [Figure 4].

Once the call was given to the infantry to leave the trenches and advance, the remainder of the 2nd Division, those who had not been affected by the gas, entered into no man’s land. Two or three northern battalions were stopped and driven back by German infantry and machine gun fire before they could reach the first German trench. The remaining brigade advanced all the way to the German second line, but they too eventually retreated to their starting positions. Observing the pinned down men, General Gough ordered the two virtually wiped out brigades to hold the line with as few men as possible, while the strongest remaining battalion was to move south into position behind 7th Division near Vermelles to attack the next day. With the 2nd Division out
of action, the remaining two divisions of the 1st Corps, the 7th and 9th, would have to continue
the battle without any assistance or protection along their northern flank. For the 1st Corps, the
common problem, aside from the gas, was that the limited number of artillery shells had little effect
on the German barbed wire.

Figure 4. A model of the PHG, which is very
similar to the “P” or “PH” helmet, the only dif-
ference being that this model has glass goggles
instead of mica. (Source: Haber, p. 100.)

Figure 5. Developed by the British Medical Services
in the beginning of May, the “black veil” provided better
better protection from German gas than what had been
issued in the previous months since the Second Battle of
of Ypres. The black veil comprised of black cotton net-
ting surrounding cotton. Notorious for being difficult
to adjust and for falling apart, this simple gas mask only
provided protection from a weak amount of chlorine and
was only effective for five minutes. (Sources: Haber, p.
45; Cotton, pgs. 101-102).

The 1st Division of the 1st Corps on the southern flank had similar problems as gas
released from the south followed the wind and collected in their trenches. The winds along the
front occupied by the 4th Corps’ 47th and the 15th Divisions, south of the 1st Corps’ lines, were
described by Rawlinson as “light but fairly favorable.”51 However, the winds were still blowing too
strongly from the south, causing the gas to float into the salient of the 1st Division.52 The southernmost
brigade of 1st Division, the 2nd, was most affected by the gas, reporting that nearly 2,000
men were incapacitated by gas blowing back into their trenches.53

The advance of 1st Division was delayed to allow the gas to drift away from their location.
By 6:34 a.m. the 2nd Brigade started its advance, but was further held up at the first German line
just south of Lone Tree because the German defenses had not been affected by the gas or by the
four-day-long bombardment.54 With the 2nd Brigade stuck at the first German line at Lone Tree,
and the 15th Division pressing south onto Bois Hugo, General Rawlinson feared that a gap in the line
would form. A division of the line did occur at 9:30 a.m., causing Rawlinson to request the
reserve forces of the 11th Corps and the 3rd Calvary.55 But his request was not honored. Instead,
command of 11th Corps was given to Haig’s First Army. It was not until 1 p.m., long after the
reserve unit could have helped stop the gap from forming, that the 11th Corps was tasked to Raw-
linson.56

The 1st Brigade, north of 2nd Brigade, pressed through the gas cloud, protected by their “P”
helmets, and emerged from the cloud only to be caught by machine gun fire from the German trench.57
By 3:10 p.m. the 1st Brigade was able to break through the second German line and attack the out-
skirts of Hulluch. The zone of barbed wire stopped many men approaching inner Hulluch, but a few were able to temporarily enter the village before they were forced back into their lines the next day. For both 2nd and 1st Division fronts, gas quickly caused chaos in battle, which further complicated the engagement. Because of shifting wind conditions, gas was able to inflict a high number of casualties in the brigades of 2nd and 1st Divisions, which prevented them from advancing and attaining their objectives. In a telephone conversation, Rawlinson noted the poor performance of the gas when he said that the “Germans [had] suffered more from artillery than gas.” Within an hour of this conversation, at 4:30 p.m., Rawlinson received reports that ammunition for 15-pounder field guns was running out.

In Conclusion of the Battle

The effects of gas at the Battle of Loos, coupled with the rush to retaliate against the Germans, prevented the Special Brigade from receiving adequate training or access to sufficient number of quality gas cylinders. Better cylinders would have prevented gas from leaking into the trench because of faulty valves and joints. Gas cloud attacks also relied too heavily on wind, making them extremely difficult to coordinate with an infantry attack. The use of gas in unfavorable wind conditions prevented the majority of the 2nd Division from participating offensively in the battle of Loos. This stopped the 2nd Division from forming a defensive flank for the other divisions in the 1st Corps. In the south, the wind blew gas into the salient of the 1st Division, forcing them to wait while the cloud moved past. This slowed the men of the 1st Division from keeping up with the 15th Division, causing a gap to form between the two divisions early in the battle. In order for a safe and successful gas attack, the British military needed a perfect wind, something impossible to guarantee no matter how much time was spent planning their attack. The British commanders also needed to use gas clouds along a smaller front where the variables of the wind would have played a smaller role on the effectiveness of gas. The British commanders needed to use gas clouds less like artillery and more as a weapon to strike fear into the enemy. If the British would have used a larger scale artillery bombardment of the enemy area with a limited gas attack, it is possible that the battle could have been a success. Major General Foulkes, commander of the Special Companies saw the battle as a great success because he believed the Germans were caught by surprise. Other commanders saw use of gas at the Battle of Loos as more of a problem than a solution to the stalemate and war of attrition. Many of the commanders in the field also did not like Foulkes reassigning their men to participate in the dangerous and laborious tasks of hauling gas cylinders to the front. These opinions forced Foulkes to appeal to the public to gather more support for further employment of gas.

Adaptations and Advances

In the time between the end of the Battle of Loos and the start of the Battle of Arras in April 1917, significant developments in British chemical warfare occurred. The British moved away from anti-gas helmets to a more modern type of respirator, providing better protection against higher concentrations of gas than before [Figures 5-7]. The British also developed and employed many additional types of gases and projectiles. Men in the Special Companies and the BEF underwent more specialized training in the employment of and protection from gas.

Shortly after the Battle of Loos, Foulkes, under the advice of Howard Livers, an officer in the Special Companies, gave permission for the metal cylinder piping to be replaced with a rubber hose along with a four-way connection, fixing both the leaking problem of the metal pipes and the problem of gas leaks that occurred while changing a cylinder. In January 1915, Foulkes was granted with an expansion of the Special Companies, gaining 21 companies, bringing Special Companies up to brigade strength. This increase in manpower gave Foulkes more flexibility in how
to employ gas. Now, he was able to use gas cylinders and also the Stokes 4" trench mortar [Figure 8], and in spring 1917, the Livens Projector [Figure 9]. Outside the realm of the Special Brigade, the British were able to develop gas shells for use by the Royal Artillery.

Figure 6. A “hypo” helmet. The protective solution in the helmet only protected against chlorine, a source of much concern to the generals on the field, who feared the Germans might begin to deploy another poisonous gas, phosgene. (Sources: Haber, p. 46.)

Figure 7. The small box respirator (SBR). Developed in late 1916 it remained in manufacture throughout the war. (Source: Haber, p. 100.)

Figure 8. Four inch Stokes mortar (Source: Richter, p. 111.)

Figure 9. Livens Projector battery. This shows how a small battery of Livens Projectors would have looked prior to being camouflaged and readied for a launch. (Source: Foulkes, p. 170.)

As the use of cylinders continued, it became increasingly difficult for Foulkes to assemble a carrying party, even if he was on good terms with the senior officer of a sector. This forced him in February 1917 to conduct a publicity campaign promoting the use of gas among the army commanders. The rallying process involved a number of steps. The first was to demonstrate that gas cylinders used in a trench did not create danger for its occupants. Foulkes conducted a number of lectures that showed the low number of occurrences in which gas cylinders awaiting dispersal had been hit by artillery and mortar shells. He also compared this occurrence to the number of casualties and deaths caused by enemy fire striking a cylinder. In the summer of 1917 Foulkes helped create a series of articles called the “Monthly Summary of Gas Intelligence,” which consisted of extracts from interrogations of captured Germans who had been gassed. For the British, these
accounts made the effect of gas by the British appear more deadly than reality. This skewing was probably compounded by the Germans' desire for the British to maintain their pursuit of gas. In spring 1917, because army commanders still viewed the use of gas cylinders with disdain, Foulkes was forced to change from the large 160 pound cylinder to a smaller 50 pound cylinder. These new cylinders were designed to be carried in a sling by one person. The concept was sound, but these new cylinders still had many flaws. They were much more portable than the heavier type of cylinder but still could not be carried through the narrow communication trenches. The smaller cylinders also did not save much in manpower. Since the cylinder was smaller, the Specials, without the help of infantry carrying parties, would have to make more trips back and forth to have the same amount of gas available, so this method of distribution potentially took longer to assemble as well as a shorter amount of time to empty.

Foulkes also tried to find a new way to discharge the cylinders without causing harm to the rest of the infantry. His new method involved loading cylinders under the fire step as before, but while the gas was discharging, the infantry remained in the support trenches away from the gas, and would return only after the gas had been released. After a while, the Germans put together what was about to happen when the infantry moved to the support trenches. The Germans then used that opportunity to conduct an artillery attack on the particular British trench, bombarding the gas officers who were going to release the gas toward the German lines.

While gas cylinders served as the vanguard of gas employment by the Special Brigade in the first years of British gas use, they also had a few companies that used the 4" Stokes Mortar [Figure 8]. This device saw some action in the Battle of Loos, but its purpose there was only to fire smoke bombs to produce a smoke screen for the advancing British infantry. It was not until spring 1916, during the Somme offensive, that the mortars were equipped with SK, a tear producing gas. Compared to most howitzer shells filled with gas, a 4-inch mortar was able to shoot a higher percentage of gas for the shell's weight. A mortar was able to shoot 7.5 lbs of phosgene, a lung inflammatory chemical, up to ranges of 840 yards. The mortar also had a higher rate of fire compared to a howitzer, but the mortar lacked the howitzer's 26,000 yard long ability.

Livens Projector

Although gas mortars saw use throughout the war, the Livens Projector launched the greatest amount of gas per weight of shell than any other weapon produced during the war. The Livens Projector first saw large-scale use during the Battle of Arras in April 1917, but Captain Percy Smith of the Special Brigade had initiated its concept in mid-1915 when he hypothesized he might be able to launch a regular cylinder from a mortar. The idea of launching a cylinder of gas was revisited by another officer in the Specials named Captain Strange, who produced a prototype and conducted experiments with the device, eventually succeeding in launching a ten gallon oil drum. Final evolution of the projector was undertaken of Captain Howard Livens of the Special Brigade. He completed work on his version of the projector in the winter of 1916.

The Livens Projector was a simple design, consisting of three main parts: a base plate, tube, and a projectile weighing thirty pounds [Figures 9 and 10]. The projector was designed to be light and easy to carry through the trenches to remove the need for assembling a carrying party for a cylinder. The smooth bore tube made it inaccurate, but successful employment of the projector relied on a launch of many gas projectiles to achieve a saturation effect. Livens first used black powder to propel the cylinders, but as the British and German lines grew more distant from each other he switched to a cordite charge to increase range.

Because of the increase in range and the ability of the device to launch a large amount of gas compared to artillery, many in the Royal Artillery started to see the use of projectors as an infringement upon their area of responsibility and attempted to prevent the projectors' use. In order
Figure 10. Interior assembly of a Livens Projector. (Source: Foulkes, p. 170.)

to bypass the Royal Artillery, Livens used his contacts in the general staff and camouflaged the names of material needed to carry out projector attacks.70 The projector’s ability to launch a 30 pound projectile up to 400 yards would eventually compete directly with cylinders and mortars in gas operations.71 Infantry commanders favored the projectors over gas cylinders because projectors did not require large carrying parties of infantry and the device was less affected by wind compared to a gas cloud.72 Years after the war Foulkes admittedly stated that he was not aware of Livens’ development of the projector, but he supported the weapon because “it proved to be a most effective means of making a gas attack.”73

As mentioned previously, the projector was designed for easy deployment and employment. When setting up for a barrage, the men of the Special Brigade would place the projectors on the ground between the support and the reserve trenches. Placement of the projectors happened only at night in order to provide some protection from Germans machine guns as emplacement took place above the protection of the trenches.74 Even though this method was easier and safer than setting up and using gas cylinders, the danger of getting shot was a constant threat.

The men of the Special Brigade soon devised a new way to set up the projectors while retaining some protection. Shallow trenches were added to the existing trenches and the tube and base plates were set up close together in these shallow pits. This form of setup was rehearsed by the men of the Special Brigade until one officer and three men could ready seventeen projectors in fifty minutes. However, the practice of grouping the projectors together damaged the tubes, because when fired collectively, the percussive force would bounce the tubes against each other, cracking the casings. To counter this, a company decided to coil rope around the tube which prevented any damage to the tubes.75 It was common for projectors set up in the standard fashion to bury themselves into the soft ground from the recoil of the weapon. The extra work of wrapping rope around the tubes did not require more effort than placing the projectors on the ground.

The inaccuracy of the Livens Projector was both beneficial and detrimental. Projectiles fired from the Livens Projectors had difficulty landing on their detonators because they flew end
over end instead of in a tight spiral. This caused the projectors to land as duds, or on occasion to fall short of hitting the German trenches. However, the unpredictable and haphazard flight paths of projectiles launched from Livens Projectors made it difficult for the German infantry to identify where the cylinders might land, enabling the British to create a constant element of surprise. Germans became fearful of gas projectors, which would upset their daily routines in the trench, forcing them to remain constantly vigilant to prevent casualties by surprise. This greatly affected the gas discipline enforced by German officers. The Germans began to recommend that all the infantrymen carry the canister filters from their gas respirators. This would allow infantrymen to breathe while they retrieved their respirators. Because of the British use of the Livens Projector and gas artillery shells, the Germans also required their infantrymen to wear their respirators when British fired artillery shells into German lines.

Just as the Livens Projector saw final development in 1916, gas shells also began to develop. At first, shells were filled with a tear-producing gas, but as the war and technology progressed the British were able to fill shells with lethal gases. Gas shells were used to a limited degree during the Battle of the Somme in July 1916. The possibility of launching gas with the aid of artillery or projectors gave gas a new dimension that permitted safer execution than the cylinders. Gas shells and projectors appeared to provide better results, but even they had some limiting qualities. The use of gas was then modified to support the Royal Artillery’s (RA) objective of neutralizing the enemy, instead of following the Special Brigade’s objective of killing the enemy.

At a conference in April 1916, General Rawlinson, now commanding the Fourth Army, stated that artillery firing gas shells needed to be used for counter-battery work and for the use against locations fortified with machine guns. As a test, Rawlinson wanted to use the tear gas chemical SK to test how well gas shells could prevent an artillery battery from firing at advancing British infantry. Rawlinson’s theory was that the gas could work in two ways, either denying access to the artillery from resupplying—buying the infantry time as they crossed no man’s land—or impairing the accuracy of the artillery because the gunners would be forced to don their gas masks. Rawlinson hoped that by protecting the advancing infantry from artillery and machine gun emplacements, the infantry could make a breakthrough as they had planned to do at the Battle of Loos. However, this use of artillery did not appear to help the British advance at the Battle of the Somme, as the RA did not possess enough gas shells to conduct an effective bombardment of local villages.

Planners of the Somme offensive saw the use of gas shells as the next big military advance. General Sir Douglas Haig began to request a supply of lethal gas shells to nullify any defensive fire, and to allow infantry to break through the German line. The idea behind using gas instead of regular high explosive (HE) rounds was that the gas had a broader area of effect, making it easier to hit a target. Unlike cylinders, gas shells provided a large increase in range and added a degree of precision. Gas shells had one disadvantage over most other offensive gas devices: they had a very limited carrying capacity. The first gas shell was nothing more than a typical artillery shell casing filled with gas instead of HE. The thick wall of the shell casing greatly reduced the shell’s capacity for carrying enough gas to be an effective weapon. In 1917, the British introduced a new, modified special artillery shell designed to carry a larger amount of gas. This shell had thinner walls, effectively doubling the capacity of the shells. The shells also had to contain a lining to prevent the corrosive chemicals from leaking through it. Early shells were lined with lead, but ceramic and eventually glass linings were developed. The British primarily used two types of gases, lethal phosgene and chloropicrin, a tear gas, to fill their shells.

One of the main problems with gas shells was matching the correct specific gravity of HE so the shell would be more stable in flight. The British chose phosgene and chloropicrin because they had a similar density to HE in a shell. Some space was left in the shells to allow the gas to expand. Each of the countries using gas shells used different methods to fill their shells. The French
method of loading a shells with chemicals from the top was the easiest way to fill their gas shells. The British, on the other hand, loaded the gas through the side of the shell and required a device to measure the amount of gas put into the shell. The need to constantly measure and maintain safety during the process of filling a shell further complicated shell production, something many manufacturers were trying to avoid, since they had just began making enough shells to match the needs of the BEF. Even with all these modifications, shells still wobbled in flight. They also produced a peculiar sound as they flew through the air. The instability of the shell while it was in flight often caused it to improperly detonate, dispersing gas in the wrong area. The tell-tale noise that the gas shell made while in flight also provided a warning to the Germans as to the type of shell it was. There were also instances in which gas shells would burst just after leaving the muzzle of an artillery piece, dispersing its contents over the British men and equipment.

The use of a standard field gun made it possible to bombard an area four miles away with gas, while a British howitzer was capable of reaching a target ten miles away. The advantage of the field gun was that it could fire more rapidly: the popular French 75 mm field gun could fire between fifteen to twenty rounds a minute whereas the British 4.5" howitzer could only fire four rounds a minute. A small artillery piece could fire shells more rapidly but would need more shells to saturate an area. A heavier gun had to fire at least 27 rounds into a specific area to have significant affect. The smallest artillery piece was a 7.7cm (3") field gun, its shells filled with three-quarters of an imperial pint of gas. The chart below shows the varied capacity of the British gas shells used during the war.

<table>
<thead>
<tr>
<th>Caliber of Artillery</th>
<th>Type of Artillery</th>
<th>Imperial Measure</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric cm</td>
<td>US</td>
<td></td>
<td>US</td>
</tr>
<tr>
<td>7.7 cm</td>
<td>3&quot; Field gun</td>
<td>.75 pints</td>
<td>.5 quart</td>
</tr>
<tr>
<td>10 cm</td>
<td>4&quot; Heavy Field gun</td>
<td>1.5 pints</td>
<td>1 quart</td>
</tr>
<tr>
<td>10.5 cm</td>
<td>4.2&quot; Field Howitzer</td>
<td>2 pints</td>
<td>1.2 quart</td>
</tr>
<tr>
<td>15 cm</td>
<td>5.5&quot; Heavy Field Howitzer</td>
<td>5-6 pints</td>
<td>3-3.5 quart</td>
</tr>
<tr>
<td>21 cm</td>
<td>8.5&quot; Howitzer</td>
<td>10-12 pints</td>
<td>6-7 quart</td>
</tr>
</tbody>
</table>

Between the Battle of Loos and Battle of Arras gas became an integral part of fighting in the trenches. Gas affected the infantry both on and off the battlefield as men were trained in gas warfare. Their training covered the advances made by the British in protective devices as well as the British offensive gas capabilities. Between these two battles the Special Brigade also underwent changes in their equipment as well as the policies and tactics they used.

In order to fix the problems encountered at the Battle of Loos, Foulkes announced to the gas officers that they and not the infantry officers were in complete control of the deployment of gas cylinders. Foulkes also ordered his men to modify parts of the cylinder assembly [Figure 1]. One modification that Foulkes wanted was to cut the pipe connecting to the cylinder from ten feet to five. This change in pipe length would make it easier to handle the pipe in the trenches when the men traveled with them and when they attached them to cylinders. The second modification to the cylinder assembly came by the advisement of Howard Lively, calling for the replacement of the parapet pipe with a rubber hose. This modification also granted ease of transport, as well as preventing gas from leaking as the metal pipes had at the Battle of Loos.

After the Special Companies made these changes to the cylinders and allowed the gas officers absolute say in employing gas, they attempted to launch a gas cloud attack against the
Hohenzollern Redoubt area on October 13, 1915. The attack was to retake the ground the British lost in the days after the Battle of Loos. Despite all of the changes made to the cylinders to prevent leaks, the trenches still filled with fumes of chlorine gas. The trenches were crowded with infantry, further increasing the effects of the slightest amount of gas. In some locations the men were so overcrowded that they were unable to "take preventive measures." The operation was a failure, prompting Foulkes to say: "The battle of 13th October was even more disappointing in its results than that of 25th September, and once again nearly all the ground gained in the first assault was lost subsequently." During 1916 and 1917 Foulkes' mind was focused on finding a way to use gas to get the best result. He saw three keys for the success of gas employment: exhaust the mask, penetrate the respirator, and surprise. The principal offensive method of gas Foulkes wanted to employ was to use a large quantity of gas to make the Germans keep their respirators on for as long as possible, eventually overwhelming the German gas respirator. The only way this could be achieved, according to Foulkes, was to use a large amount of gas cylinders, "more than what could be convenient," to create a constant stream of gas. During breaks in the gas cloud, the British would also employ smoke to make it difficult for the Germans to tell when gas had stopped or was on break.

Only partial penetration of the German respirators was possible. One such chemical was chloropicrin, also known as SK. This chemical was both a lethal and a tear-causing agent. Its lethal properties were similar to that of phosgene or chlorine, causing an inflammation of the lung tissue. But unlike phosgene or chlorine, it was not as lethal, and required a high concentration to kill. Aside from causing the lungs to inflame, chloropicrin produced heavy coughing and vomiting, which would cause German infantrymen to remove their masks. With their masks removed, the German infantrymen were susceptible to other gases. To achieve surprise the Special Brigade relied on the use of such weapons as the 4" Stokes mortar, Livens Projector, and artillery firing gas shells. Gas cloud attacks at night were known to happen from time to time in order to achieve surprise.

After the Second Battle of Ypres gas advisors gave crash courses in gas defense to the infantry. Eventually, in 1916, the BEF instituted formal training for the infantry when they created the first gas school meant to inform noncommissioned officers (NCOs) about gas and to build confidence in the respirator design. Divisional and battalion level NCOs trained for two weeks before they returned to their units to provide gas instruction to their fellow infantrymen. Regimental officers also received special training by gas advisors, but their training was significantly shorter than that of the NCOs. The officers' training was geared toward making them more knowledgeable about gas defense, allowing them to make regular inspections of their infantry's gas equipment, and to maintain a strong gas discipline by performing gas drills.

This training covered many subjects, from determining the best conditions and locations for the use of gas, to the advantages and disadvantages of British respirators. According to lecture notes, the best conditions for using gas were during early summer when the air was warm and the wind was still. These conditions enabled the gas to linger in an area longer, causing more casualties. Of equal importance was knowing the areas most likely to receive a gas attack, including wooded areas and dugouts. The woods made effective targets because gassed infantrymen could easily become disoriented and lost. Dugouts provided an area for gas to collect in dangerous concentrations for as long as an hour after a gas attack. The instructors also taught regimental officers how to correctly estimate wind speed by observing their surroundings so they would know if a gas attack was possible. The instruction men received about gas masks was more often an overview of the history of the gas masks used during the war, a listing of the advantages and disadvantages of each style. Instructors also went through the different parts of the Small Box respirator [Figure 7] describing the care needed to maintain their masks.

Between 1916 and 1917 the British infantry gained more knowledge about the appropriate
ways to employ gas. Their instruction also helped them become more acquainted with their respirators. The Special Brigade in early 1915 corrected the assembly problems of the gas cylinders. These corrections still allowed some gas to continue to leak into the trenches. The Special Brigade also developed the Livens Projector which made gas easier and safer to use. Foulkes used the projector and the gas cylinders to develop a policy of gas assault by using a large quantity of gas in the hopes of overwhelming the German respirator.

**Battle of Arras, 1917**

All of the advancements made by the British in gas weaponry, education, and policies came together at the Battle of Arras on April 9, 1917 [Map 3]. The Battle of Arras was much like the Battle of Loos, in that it was a joint offensive between the French and the British. Again the French hoped their army, under the command of General Robert Nivelle, could break through the German lines in one large attack. They then planned to cut through the German reserves, allowing both the French and British infantry to maneuver their forces and rout the German army. Sir Douglas Haig, now British commander of the BEF, was not as optimistic about the outcome of the battle. The British hoped simply to gain Vimy Ridge northeast of Arras and to eliminate the salient around Bapaume in this new offensive.

**Map 3.** The Battle of Arras. (Source: Richter, p. 179. Note that the map has been changed from the original.)

In February 1917 the German forces conducted a planned withdrawal to fortified locations further east, called the Hindenburg Line. This convinced the allied commanders that Germany
was close to surrendering, so they altered their original plans for the offensive. In reality, the Germans were strengthening their defenses by creating a “flexible defense.” In a “flexible defense,” the Germans lightly held the front line and then counterattacked with great force, driving the attackers from the lines. The British decided to strike between “Arras and Vimy with the greatest possible strength with the view of penetrating [the German] defenses.”

In March the British began their preparations for the Arras offensive by conducting a number of raids along the German lines and stockpiling equipment. On the morning of March 1, 1917, the Canadian Corps, with the assistance of a company from Special Brigade, used gas cylinders to assist with preliminary reconnaissance of the German position on Vimy Ridge. The weather was poor but the wind was favorable enough to open up the cylinders containing White Star, a mixture of 50 percent phosgene and 50 percent chlorine. Shells burst several of the pipes while the discharge of gas was taking place and the trench filled with gas. The wind once again changed direction forcing the gas officers to cancel the use of more gas. The cancellation allowed the Germans to reorganize and prepare for the Canadian reconnaissance force. When the Canadians left the safety of their trench, they came under heavy fire from machine guns causing them to withdraw to home positions after suffering heavy losses.

By March 25 the 160 batteries of artillery, which were going to participate in the British attack along Arras, began to receive their first allotment of shells. Each battery was furnished with 6,800 shrapnel and lyddite shells and 4,000 gas shells. At the start of the battle, the First Army possessed 40,000 gas shells and the Third Army had 60,000 ready for use by the Royal Artillery. Gas officers of the Special Brigade once again came to the battle unprepared. From January through February of 1917 they trained on the Livens Projector, but they used dummy projectiles of wood rather than real projectors. The real projectiles did not arrive in France until early April, days before they were to be used in the Arras offensive. While projectors were designed for ease of use, the inexperienced Specials forgot to plan for real battlefield conditions. Once the gas officers received their supply of projectiles, they went to work emplacing them.

One of the first locations the British used the Livens Projectors was between the French towns of Tilloy and Thelus. The five mile stretch between Tilloy and Thelus contained some 2,300 projectors with projectiles filled with White Star. These projectors were fired on April 4, 1917 in preparation for the Arras offensive. Also taking part in the preliminaries of the Battle of Arras was the Royal Artillery. The artillery used two different types of gas shells, one was filled with a mixture of an arsenious chloride and phosgene while the other was filled with a arsenious chloride, chloroform, and hydrogen cyanide. On April 9 the last gas bombardment occurred before the infantry advance took place. The assault began at 2:30 a.m. and lasted until 6:30 a.m., continuing through a snowstorm in which winds reached up to 13 mph. The infantry of Third Army was able to occupy up to the second German line but was stopped by the third German line. Despite the heavy use of gas shells and projectors, the British forces were unable to break through the German line. By nightfall all the land captured by the Third Army was regained by the Germans. As the preparations for the Arras offensive were being deployed, the Special Brigade was ordered to launch their Livens Projectors against Bullecourt. The Special Brigade sent two companies to arrange 320 projectors into firing position facing Bullecourt. The men had a difficult time assembling and transporting the projectors because of poor ground conditions, but the shoot was viewed as a mechanical success. Even though the operation of the projectors went perfectly, the men were still repulsed because the projectors had little effect on the German infantry.

At the same time as the result of the assaults along the entire British front, the Canadians conducted an assault on Vimy Ridge. Initially the Special Brigade installed 600 projectors in support of the Canadian advance. However, none of these projectors saw use because the weather conditions made it impossible launch them. Instead of gaining support from gas the Canadians
used regular HE artillery to weaken the German forces on the ridge. The Canadian Corps captured and retained most of the ridge on April 9th. The remainder of the ridge they were able to take the next day.\textsuperscript{101} The Canadians, because of their previous bad experience of with the use of gas in March, used only regular artillery shells. High explosive artillery shells again proved more effective at inflicting causalities than the use of gas. Yet the British pursued gas despite its drawbacks and complications.

In conclusion, the British first used poison gas as a retaliatory agent against Germany's use of the gas in the Second Battle of Ypres. Later they attempted to use gas in the hopes of breaking German lines, returning to a war of movement. The British tried to break through the German lines at the Battle of Loos, but they failed miserably. The British forces were too quickly assembled and too poorly trained and equipped to act as a functional, efficient combatants. These factors, along with poor decisions and misguided orders from General Haig, maintained the constant failure of gas elements in battle. In both of the battles, the generals used gas in conditions where weather and wind were unfavorable, causing the gas to have no effect at all or do more harm than good.

\textbf{Appendix. Glossary}\textsuperscript{102}

\textbf{Army Corps:} formation consisting of two or more divisions.
\textbf{Battalion:} Infantry unit of three or four companies, totaling around a thousand men.
\textbf{Battery:} an artillery unit, consisting of four to sixteen guns.
\textbf{Brigade:} a subunit of a division, made up of four to six battalions.
\textbf{British Expeditionary Force:} the initial six divisions of the British regular army sent to France at the beginning of the war.
\textbf{Breakthrough:} the penetration of the enemy's defensive line to allow operations in the open country beyond.
\textbf{Division:} the smallest military unit consisting of all arms and organized for independent action.
\textbf{General headquarters:} the department of the Commander in Chief responsible for the planning and conduct of military operations.
\textbf{Hindenburg Line:} A prepared section of defensive line that the Germans withdrew to in March 1917.
\textbf{Noncommissioned Officer:} a junior officer in a section or squad.
\textbf{Redoubt:} A fort or a fort system that usually consists of an enclosed defensive emplacement outside a larger fort. It is used to protect soldiers outside the main line of defense.
\textbf{Salient:} A projection of forces into enemy held territory.

\textbf{Notes}
\textsuperscript{2} Gilbert, 21.
\textsuperscript{4} \textit{Ibid}, 68-69.
\textsuperscript{5} Gilbert, 33.
\textsuperscript{6} Keegan, 98.
\textsuperscript{7} \textit{Ibid}, 99.
\textsuperscript{8} \textit{Ibid},100.
\textsuperscript{9} Gilbert, 70.
\textsuperscript{10} Keegan, 122-123.
\textsuperscript{11} \textit{Ibid}, 127.
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15. Ibid., 31.
16. Ibid., 31.
18. Haber, 32.
20. Ibid., 44.
23. Ibid., 18-20.
25. Ibid., 17.
27. Richter, 17; 28.
28. Ibid., 33.
30. Palazzo, 54.
32. Palazzo, 59.
34. Ibid., 61.
36. Ibid., 3.
37. Ibid., 2.
39. Haber, 56.
41. Ibid., 1.
42. Richter, 61.
44. Ibid., 69.
45. Gough, 105.
46. Ibid., 104.
49 Ibid, 71.
50 Gough, 111.
52 Rawlinson, Telephone Conversation, 25 September 1915, 3.
53 Ibid, 1.
54 Palazzo, 69.
55 Rawlinson, Telephone Conversation, 25 September 1915, 3.
56 Ibid, 4.
57 Palazzo, 70.
58 Rawlinson, Telephone Conversation, 25 September 1915, 5.
59 Ibid, 4.
60 Ibid, 6.
63 Foulkes, “Gas!” The Story of the Special Brigade, 184.
64 Haber, 248.
65 Richter, 184-85.
66 Haber, 180.
67 Ibid, 180.
69 Haber, 181.
70 Richter, 162.
71 Ibid, 165.
72 Ibid, 166.
73 Foulkes, “Gas!” The Story of the Special Brigade, 167; 172.
74 Haber, 183.
75 Richter, 187.
77 Palazzo, 100.
78 Ibid, 99.
79 Richter, 130.
80 Haber, 64.
81 Ibid, 86.
82 Ibid, 65.
83 J.W. Lewis, Diary for 1917, April 1917, Special Collections, Imperial War Museum, London, 82.
84 Ibid, 64.
86 Richter, 96.
87 Foulkes, 89.
88 Palazzo.
90 Haber, 136.
91 Strutt, 13-20.
93 Palazzo, 114.
94 Richter, 175.
95 Lewis, 72.
96 Palazzo 124.
97 Richter, 180.
99 Palazzo, 115.
100 Richter, 179-180.
101 Palazzo, 116.
102 J.M. Winter, The Experience of World War I (New York: Oxford University Press, 1995), 69. All terms derived from this text.

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Chain Migration of Latinos to St. Paul, Minnesota

by

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Introduction

During the past two decades, the Twin Cities have experienced an in-migration of people from Latin America, Asia, and Africa. St. Paul's Latin-American community has grown significantly during this time. Various reasons for this chain migration have been suggested. Through collection of primary and secondary sources, the push and pull factors can be observed. This research focuses on four questions: what is the basic migration history and geography of St. Paul Latinos? why did they come? what is their livelihood now? and how do they organize themselves socially to retain their ethnic identity and culture? The use of ArcMap and Adobe Illustrator allowed me to produce maps that demonstrate this group's basic migration patterns.

Defining the People

Latinos are becoming the largest minority group in the United States. Some assumptions about Latinos based on general knowledge are that Latinos are low-income and come to the United States to seek better employment opportunities. Some tightly-knit Latino communities exist in St. Paul, Minnesota as a result of chain migration. The communities have made a significant impact culturally and economically on the surrounding area.

The terms Latino, Chicano, Hispanic, and Mexican are often interchanged in Americans' everyday language, but the two most important for this research are Latino and Hispanic. Merriam's Collegiate Dictionary defines Latino as "a native or inhabitant of Latin America. Short for Latino Americano (1); a person of Latin-American origin living in the U.S. (2)." As for Hispanic, the definitions are "Latin hispanicus, from Hispania Iberian Peninsula, Spain (1); of, relating to, or being a person of Latin American descent living in the U.S., especially: one of Cuban, Mexican, or Puerto Rican origin (2)." While the dictionary and Census Bureau use these terms almost interchangeably, they are not interchangeable to Latino or Hispanic natives. For the latter, a Latino is someone from Latin America and a Hispanic is someone from Spain. The United States Census Bureau uses these terms interchangeably, and before the 1980's the census only used the term Mexican. If these terms are used incorrectly, they may cause offense. Therefore, in this research, the term Latino will always be used unless in a reference to another source that employs another term.

History

Migration from Latin America to Minnesota is not a new phenomenon. In the 1850's the first Mexican arrived in the Minnesota territory to seek work, and by 1880 six Mexicans were counted by the U.S. Census, drawn to the United States because of seasonal agricultural field work. The sugar beet industry expanded in Minnesota, and when a factory was built in 1897 in St. Louis Park, immigrant workers were used. At first these workers were primarily German and Russian; however, when World War I occurred, alternative workers needed to be found. The Mexicans provided the replacement and the population grew as a result.
The Study Area

The pictures below show the Latino influenced landscape of St. Paul. While these buildings appear in West St. Paul, similar ones are found throughout the city. In Picture 1 this Mexican flag on Isabel Street joins many others hanging outside of Mexicans’ homes. Picture 2 shows El Primo (“The Cousin”), a shop on César Chávez Street that sells clothing from the “wild west” to the Latino community. The Mexicans call this type of clothing “Rancheros.” The majority of the customers are male; however, they are beginning to sell women’s clothing as well. The first sign in Picture 3 reads: “Taxes, Translations, Notaries, Mortgages and Sale of Houses. Always solutions for the community.” The second sign reads: “We speak Spanish. Auto Insurance. All risks and problems. We accept international and Mexican licenses.” Most signs throughout the area are in English and translated into Spanish. In Picture 4 this cafe, part of El Burrito Mercado on César Chávez Street, carries traditional designs from Mexico. Brightly colored buildings such as this can be seen throughout the city. The type of art in Picture 5, influenced by traditional murals that can be seen throughout Latin America, appears on the side of a restaurant and is advertising for shops in the area. Billboards like the one in Picture 6 can be seen throughout St. Paul. This billboard reads: “The best consultations never go out of style.” The fact that this is a Wells Fargo advertisement shows that Latinos are making a big impact on the community.

While Latin America includes all of Mexico, Central America, South America, and the Caribbean, Figure 1 shows the region from which Latino migrants in the study area originated. These persons do not represent the entirety of St. Paul’s Latino migrants.

Many people from Latin America have migrated to the United States, and Figure 2 shows the current distribution throughout the United States according to the Census. The majority of the Hispanic/Latino population is located in the southwest corner of the country, land owned by Mexico before the Treaty of Guadalupe. However, this map also presents an anomaly—the large Hispanic/Latino population in parts of Minnesota. Minnesota’s agriculture attracted many Hispanics/Latinos to this work sector.
St. Paul’s Hispanic/Latino population in 1990, shown in Figure 3, is located near the Mississippi River, in great part in an area called West St. Paul. By 2000 the Hispanic/Latino population had grown, as the percentage increases in Figure 4 and Figure 5 show. As certain areas become more concentrated with Hispanics/Latinos, other areas are just beginning to see a growth in numbers. Figure 5 shows in which areas the Hispanic/Latino population is spreading—primarily in the downtown and West St. Paul regions.
The hypothesis was made earlier that Latinos are low income. It is reasonable to assume that people with low incomes are more likely to rent than own. Figure 6 shows that the majority of the population in St. Paul rents. In some areas where the Hispanics/Latinos are located, however, the percentage of renters is lower. Since the percentage of renters is spread throughout the city, it is not clear how much of the Hispanic/Latino neighborhoods are renters. Correlations, which are presented later, can help to determine to what extent Hispanics/Latinos are renting.

Another method to determine if Hispanics/Latinos are low income is to look at the income levels themselves. Figure 7 presents the average or median household income by census tract. The highest household income levels appear to be outside the areas where the majority of Hispanics/Latinos live. Figure 8 shows that nearly 75% of the Hispanic/Latino population is Mexican—the reason why many non-Hispanics/Latinos believe that all Hispanics/Latinos in St. Paul are Mexican. The most rapid increase in population has occurred in the last few decades. Figure 9 demonstrates that while the total population in St. Paul has fluctuated, the Hispanic/Latino population has steadily increased.

Migration Patterns & Problems

Chain migration is defined as an “immigration process whereby a small number of pioneers, who make the first moves to set up a new home in a new place, send information back home that encourages further outmigration from the originating area.” Luis Gárzon, the first Mexican to migrate to Minnesota in the 1850s, and other men like him, travelled to the United States to seek
better employment. Many travelled first to Texas, California, Illinois, or Florida, before arriving in St. Paul. Many also paid a “coyote” to get them into the United States illegally. Using a “coyote” is both expensive and risky, and some migrants die on the trip. They oftentimes get dropped off in random places in the United States. Once they find suitable employment, they send letters home telling family and friends to come to St. Paul for available jobs. Once enough people have migrated to a community, Hispanics/Latinos begin to migrate from Latin America directly to St. Paul, MN. Some plan to stay in St. Paul for a certain amount of time, such as a year or two, and then return home, but many others intend on remaining permanently. The population has grown to 22,715 Hispanics/Latinos out of a total St. Paul population of 287,151.

The Hispanics/Latinos have had a great cultural impact on St. Paul, attested to by the streetscape of West St. Paul. Spanish is spoken in the streets and the shops of this neighborhood, and most grocery stores in St. Paul sell food from Mexico. The city government acknowledged the Hispanic/Latino presence in the area by changing the name of the major thoroughfare in West St. Paul to César Chávez Avenue. Catholic churches also conduct services regularly in Spanish.

Traditional Hispanic/Latino celebrations such as Cinco de Mayo are celebrated in St. Paul. Many area shops sell only products from Latin America. There is a section of the official St. Paul newspaper, the Star Tribune, called “Gente de Minnesota” (People of Minnesota) that is written completely in Spanish with news on the Hispanic/Latino community in St. Paul, as well as news from Latin America.

Although it seems they have adjusted well, the Hispanics/Latinos have encountered many difficulties in transitioning to this Minnesota community. The older Hispanic/Latino population has a harder time learning English than the younger. Often men take jobs where English is not required, such as construction. However, they experience discrimination at work and cannot speak enough English to defend themselves. Another difficulty they face are constantly changing immigration laws. The events of September 11th complicate this further because the United States has made it harder for immigrants to stay in the country. It often takes years for all of the paperwork to go through. This makes it difficult for migrants who want to become U.S. citizens.

Families are separated because of immigration laws. For instance, sometimes a husband and wife could come to the United States hoping to become citizens. If either of their work permits terminates, and he or she cannot get another one, that person is required to return to the country of origin.

The law requires migrant workers to live in the U.S. for ten years before they become eligible for citizenship. The immigration laws change yearly; however, if a migrant worker keeps a
low profile, then the government will go by the laws of ten years ago. Ironically, some of the jobs these persons migrated here to do are moving back to Mexico or to China for cheaper labor.

**Personal Stories**

Primary sources, including interviews and surveys, add depth to the picture gleaned from Census data. The author conducted these in Spanish unless the participant spoke English fluently. Interviewees included two organization leaders, three shop owners, and twenty-one individuals who responded to questionnaires. The locations of these shops and organizations are found on Figure 11. Additional stories were found in secondary sources, which include magazines, newspapers, journals, and books featuring immigrants from Latin America. Both the perspectives of the Hispanic/Latino population and non-Hispanic/Latino population are investigated.

![Image](image-url)

**Figure 11.** Location of businesses, services, and shops with Hispanic/Latino-sounding names in West St. Paul.

The author initially obtained a list of all the shops and restaurants in St. Paul with Hispanic/Latino-sounding names. The author then rang them to find out if they were authentic or American chains. Setting up appointments proved especially difficult as the survey was designated to take a minimum of 10 minutes, and persons claimed that they were too busy. Many of these persons owned more than one business, for instance, and were frequently out of town. Organizations proved better contacts and led to other resources, such as a church or other groups with large Hispanic/Latino membership. One church, for instance, had 800 Hispanics/Latinos using their services: 80% were Hispanic/Latino immigrants, most of whom were illegally in the United States.

Both the surveys and the responses to the questionnaire spoke to a difficult transition to St. Paul, although many organizations exist at the moment to assist immigrants. Many Hispanics/Latinos claimed that when they arrived in St. Paul they had no help. However, “chain migrants,” ones who came because relatives told them to, were better off. These testimonials contradict evidence of Hispanic/Latino organizations, such as Our Lady of Guadalupe, that have been around since the 1980’s. Most of the interviewees arrived in the last decade. All respondents said that they came to St. Paul in particular because the city offered them better economic opportunities—better
than those in another part of the United States where they had lived and better than Mexico. Most sent money home, and a few claimed to have helped relatives or friends to come to the States. Interviewees also stated that no division of labor exists between genders in their home countries, although children sometimes work. Most respondents did not speak English, or were learning it, whereas their children spoke both English and Spanish fluently.

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<td>Percent Hispanic Change, 1990-2000</td>
<td>0.813</td>
<td>0.504</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Percent Renters</td>
<td>0.360</td>
<td>0.275</td>
<td>0.370</td>
<td>1.000</td>
</tr>
<tr>
<td>Median household income in 1999</td>
<td>-0.449</td>
<td>-0.359</td>
<td>-0.438</td>
<td>-0.743</td>
</tr>
</tbody>
</table>

Conclusions
The strong correlation (.91) between 1990 and 2000 Hispanic/Latino census tracts indicates that new Hispanic/Latino immigrants are settling in areas that previously had large populations of Hispanics/Latinos. The weaker correlation (.5) between 1990-2000 change and 1990 Hispanic/Latino population suggests an expansion of the community into other parts of St. Paul. The lower correlation between percent renters in both the 1990 and 2000 Hispanic/Latino population somewhat contradicts the hypothesis that these immigrants are low-income. There is a fair degree of home ownership within the tracts that contain large Hispanic/Latino populations. However, the negative correlation between median income and Hispanic or Latino population shows that they live in poorer areas than the average St. Paul resident. In conclusion, correlation results show that St. Paul’s Hispanics/Latinos are still poor. Not all of them rent, which shows that even though they are poor, they have a better standard of living than they did in their country of origin.

Bibliography
Women's Lives in Rural Wisconsin During World War II: Organizing and Rationing

by

Jacquelyn L. Dumin, Department of History
Faculty Mentor: Dr. Jane M. Pederson

Introduction

For 20 months he was a German POW. That is when they captured them guys. They were in Africa and then they were marched to Germany. He said that was where he got sick. His stomach was all upside down because they didn’t get anything decent to eat, and he would tell you, you would look at your plate and you would see either a dog’s tongue or something like that. He would get so sick. He was terrible at eating. I tell ya. Then 20 months. They had to go on a different farm in Germany and do the crops, plant and dig up the potatoes. Then the Russians released him and then they marched to France. From France they came home and that was after 20 months... He had it for years. It was with his stomach anyway from not having enough or the wrong kind of food. I guess in Africa, all they did was eat fruit off the trees. Then they had to get to Italy. In Italy, they were captured and they had to walk to Germany. He said there were three guys who had one loaf of bread. He was skinny. I'll tell ya. No matter what he ate, just wouldn't agree with him.

This quote describes the experience Ruth Wegner’s husband encountered while a POW in Germany. World War II definitely affected Wegner. Because of it she constantly looked after her husband’s medical condition, and she held the job off the farm because her husband could not. Wegner did not speak bitterly about the experience; she spoke as if it happened to everyone. The war undeniably affected her greatly. This one woman’s experience shows how World War II affected the lives of rural small-town women, not through local government or organizations, but through their individual lives. To discover the effects on women’s personal lives two towns will be studied, Park Falls in Price County, Wisconsin, and Butternut in Ashland County, Wisconsin.

Why study two towns separated by county lines? Because the separation exists only in government documents, the connection between the people creates a situation that to study only one town would neglect a large part of the town’s history. Park Falls lies on the northern boundary of Price County. Five miles north on Hwy. 13, Butternut lies on the southern boundary of Ashland County. The connection between the towns can easily be seen when looking at maps of both counties. (See Figures 1 and 2.)

Figure 1 shows how close Butternut and Park Falls lie to one another geographically. This map also shows the isolation most towns on Hwy. 13 experience. Another town, Fifield, must be considered. Fifield lies south of Park Falls on Hwy. 13; although not included in this study Fifield also lies close to the larger city of Park Falls. True of all towns in north central Wisconsin, the people rely on one another. A family may live in one town but work in a neighboring community. Park Falls and Butternut hold a unique position because of the close family ties binding the towns. More extended families fluidly move between Butternut and Park Falls than between Park Falls and Fifield, or any other set of town in the area.
Figure 2 shows that no town in Ashland County borders Butternut; it exists in isolation from the rest of Ashland County. The map also shows how close to the border Butternut lies, and not until you travel halfway through Ashland County, toward Lake Superior, do numerous other towns appear. Because of this isolation Butternut became a de facto member of Price County.

The main information used to study Butternut came from the town’s newspaper, The Butternut Bulletin, which ran throughout the World War II years, as well as oral histories and letters from women who lived during those years. For the study of Park Falls, Price County documents, and the local newspaper, The Herald, were used. The Herald also ran during the war years, with editions still being published. The Butternut Bulletin ended printing in 1967.

![Figure 1. North Central Wisconsin. Source: www.northgoods.com/map_nw.cfm. Accessed 9/24/2005.](image1)

![Figure 2. Ashland County. Source: www.kinquest.com/.../atlas/Ashland.html. Accessed 9/24/2005.](image2)

People in these communities prospered during the war years. Personal sacrifices did occur, but typically the people and economies thrived. The greatest impact of World War II on north-central Wisconsin did not occur at the government or economic level; it occurred at the personal level. The women of Park Falls and Butternut, Wisconsin watched loved ones and friends join the military and leave during World War II. They participated in the homefront war effort through monetary donations as well as food rationing. But, they also carried on with their lives. They went to high school and graduated. They enjoyed recreational activities like the Price County Fair, and especially the dance halls. This work will explore many of these areas to discover what women on the homefront in small town rural Wisconsin experienced during World War II.

Demographics

Not until the turn of the twentieth century did the villages of Butternut and Park Falls come into existence. In 1901 Park Falls became independent, Butternut in 1903, both created from parts of surrounding unincorporated communities. Table 1 shows the population trends of the towns through the 1960’s, with current population included.

The relative population spike in Butternut in 1940 cannot be accounted for in any document located thus far. Relatives possibly moved back to the family farms during the depression for the comparatively easy lifestyle. Other than this irregularity, the population of the town steadily decreases to the present. The population of Park Falls increased until the 1950s then declined into
the present. Because of the difficulty attracting industry to the area people needed to find work outside farming to provide a comfortable living, and they possibly moved out of the area.

<table>
<thead>
<tr>
<th>Date</th>
<th>Population of Butternut Village</th>
<th>Population of Park Falls City</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>717</td>
<td>1972</td>
</tr>
<tr>
<td>1920</td>
<td>618</td>
<td>2676</td>
</tr>
<tr>
<td>1930</td>
<td>604</td>
<td>3036</td>
</tr>
<tr>
<td>1940</td>
<td>669</td>
<td>3252</td>
</tr>
<tr>
<td>1950</td>
<td>522</td>
<td>2924</td>
</tr>
<tr>
<td>2000</td>
<td>418</td>
<td>2703</td>
</tr>
</tbody>
</table>

Because of the rural nature of the area, many people did not live in the incorporated towns. The population of the counties follows the trend of Park Falls, as seen in Table 2 below. The population increased until roughly 1950 and then declined. Ashland County's population, because of its location on Lake Superior, is consistently larger than Price County's, but Ashland County still portrays the trend of a peak and than a decrease.

<table>
<thead>
<tr>
<th>Date</th>
<th>Ashland County Population</th>
<th>Price County Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1860</td>
<td>515</td>
<td>785</td>
</tr>
<tr>
<td>1870</td>
<td>221</td>
<td></td>
</tr>
<tr>
<td>1880</td>
<td>1559</td>
<td>5,258</td>
</tr>
<tr>
<td>1890</td>
<td>20,063</td>
<td>9,106</td>
</tr>
<tr>
<td>1900</td>
<td>20,176</td>
<td>13,795</td>
</tr>
<tr>
<td>1910</td>
<td>21,965</td>
<td>18,517</td>
</tr>
<tr>
<td>1920</td>
<td>24,538</td>
<td>17,284</td>
</tr>
<tr>
<td>1930</td>
<td>21,054</td>
<td>18,467</td>
</tr>
<tr>
<td>1940</td>
<td>21,801</td>
<td>16,334</td>
</tr>
<tr>
<td>1950</td>
<td>19,461</td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>17,375</td>
<td>14,370</td>
</tr>
</tbody>
</table>

Statistics about these two counties, and the specific towns, in the decades prior to World War II provides an understanding of who populated the community during the war. In the 1930s published census Park Falls total population numbered 3,036, with 1,592 males and 1,444 females of these. 2,994 considered themselves white; no one self-identified as Negro, which leaves the race of 42 people unknown. 2,571 people marked themselves as native white and 423 foreign born white. In the 1940s census Park Falls had 3,252 residents with 1,699 males and 1,553 females. The gender ratio from 1930 to 1940 remained steady with men outnumbering women in 1930 by 148 and in 1940 by 146. 2,934 considered themselves native white while 318 considered themselves foreign-born white. No one self-identified as Negro. All residents responded this time. Table 3
illustrates the age distribution of Park Falls residents in 1930 and 1940.

<table>
<thead>
<tr>
<th>Age in years</th>
<th>Number of People (1930)</th>
<th>Number of People (1940)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 5</td>
<td>342</td>
<td>275</td>
</tr>
<tr>
<td>5-14</td>
<td>688</td>
<td>563</td>
</tr>
<tr>
<td>15-24</td>
<td>527</td>
<td>622</td>
</tr>
<tr>
<td>25-34</td>
<td>471</td>
<td>529</td>
</tr>
<tr>
<td>35-44</td>
<td>406</td>
<td>443</td>
</tr>
<tr>
<td>45-64</td>
<td>496</td>
<td>650</td>
</tr>
<tr>
<td>65 and over</td>
<td>105</td>
<td>170</td>
</tr>
</tbody>
</table>

The two largest cohorts of the Park Falls population for 1930 came from the 5-14 and 15-24 year old categories. These two cohorts included the people who grew up and started families, and volunteered for armed service during World War II. The group of women interviewed from Butternut also represents this age cohort. Interesting to note is the drop in this cohort’s numbers from 1930 to 1940 in Park Falls; a loss of sixty-six people occurred between these years.

Butternut’s population in 1930 amounted to 604 residents. Of this number, 301 were male, and 303 were female, providing an equal gender ratio. All 604 counted themselves as white with 527 being native white. This leaves 77 who counted themselves as foreign-born white. In 1940 Butternut had 669 residents, 350 males and 319 females. The gender ratio by this point became skewed with more males than females. 611 considered themselves native white and 58 considered themselves foreign-born white; no one self-identified as Negro. Table 4 shows the age distribution of Butternut in 1930 and 1940.

<table>
<thead>
<tr>
<th>Age in Years</th>
<th># of People (1930)</th>
<th># of People (1940)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 5</td>
<td>82</td>
<td>68</td>
</tr>
<tr>
<td>5-14</td>
<td>131</td>
<td>122</td>
</tr>
<tr>
<td>15-24</td>
<td>85</td>
<td>111</td>
</tr>
<tr>
<td>25-34</td>
<td>74</td>
<td>100</td>
</tr>
<tr>
<td>35-44</td>
<td>105</td>
<td>75</td>
</tr>
<tr>
<td>45-64</td>
<td>83</td>
<td>139</td>
</tr>
<tr>
<td>65 and over</td>
<td>44</td>
<td>54</td>
</tr>
</tbody>
</table>

As in Park Falls, the largest cohort in 1930 was the 5-14 cohort. But noteworthy trends between these years include the increase of fifteen people that occurred in the 15-24 cohort in 1930 to the 25-34 cohort in 1940, as well as an increase of thirty-four people in the 35-44 cohort in 1930 to the 45-64 cohort in 1940. This lends further evidence to the theory that people returned to Butternut during the Depression.
Nationality

7,673 foreign-born whites numbered among the 17,284 residents of Price County in 1930. This leaves 9,611 residents as native born, probably from the county itself. The top three countries of origin for foreign-born whites in 1930 included Germany (2,052), Czechoslovakia (1,599), and Sweden (1,101). The remainder of foreign-born residents came from many different countries with Norway, Poland, and Finland topping the list of smaller groups.²

By 1940 only 3,014 persons in Price County reported being born in a foreign country. Of those, 467 came from Germany, 849 from Czechoslovakia, and 473 from Sweden. The number of foreign-born citizens of Price County dropped significantly between 1930 and 1940. A portion of this decrease can be accounted for by the death of first-generation immigrants.³

These numbers provide a picture of Park Falls and Butternut as they approached World War II. White natives primarily filled the area; many were children or grandchildren of immigrants. A few foreign-born whites, mainly from Germany, Czechoslovakia, and Sweden, also populated the area. The gender distribution was even in Butternut in 1930 but not 1940, and more males than females lived in Park Falls over both decades. With a relatively young median age the towns had many women and men coming of age during the War. Though this area does not show unique characteristics, understanding the demographic information prior to the war allows for a greater understanding of the world women lived in during World War II.

The Women Interviewed

The importance of women's voices cannot be understated. Five women whose ages at the time of World War II ranged from early teens to mid-thirties were interviewed. They described their lives before and during the war, as well as provided a brief synopsis of their postwar lives.

Born in 1928 and twelve when the war began Marge Drager married in 1953 at the age of twenty-five and had four children, all born in Park Falls. She represents the largest heritage group, Lutheran and German-Norwegian. A nightmare of enemy attacks during WWII was the first memory she recollected when interviewed. Whenever a train passed by her house she feared a Japanese attack on her neighborhood. Otherwise, she provided memories of her life as a teenager during World War II.⁴

Similarly Marion Linsmeyer considers herself Lutheran and of German-English heritage. Born in 1921, the fifth of eleven children, she married in 1939 and had her first child in 1944. Linsmeyer provided the view of a wife and mother during the World War II years. Many close friends of Linsmeyer entered the armed services, as did her brother. She ultimately had three children, and after her first husband passed away remarried. Linsmeyer provides insights into the affect of the war on a housewife.⁵

Also a Lutheran and of German heritage, Marion Russell, born in 1924, was one of three children. Since Russell graduated from high school in 1942, she provided insight about becoming an adult during a war. This information included memories of rationing, dating, and socializing.⁶

A classmate of Russell's, Ruth Wegner, provided similar information. Also born in 1924 Wegner, one of five children, provided the unique perspective of marrying a World War II former prisoner of war. Because her husband's continued health programs stemmed from his time as a prisoner of war, World War II forever altered Wegner's life. She also considers herself a Lutheran and of German heritage.⁷

The last woman interviewed, Dixie Smart, provides a view not consistent with the other women. Born in 1912, one of five children, she married in 1937 and was twenty-eight by the time the war started. Smart considers herself an Episcopalian and of mixed descent. About halfway through the war Smart moved with her husband and child to Minnesota where they found work in war industry. Because of her limited time in Butternut she could not provide information about
the town at the end of the war.⁸

These women provided invaluable, firsthand information about life in their small town during World War II. Their words, used through this work, illustrate the real life of people whose lives were affected. This knowledge can sometimes be lost when only looking at government documents or newspapers.

North Central Wisconsin During World War II

Economic Prosperity

The economy of the area had never been strong. The majority of the area surrounding both towns consisted of farmers and some continued lumbering. Significantly, the prosperity of the area increased during the war. A resolution from the Price County Board dated November 13, 1941, shows the economic hardships existing before the war,

Price County has 1977 families located on farms with less than twenty-five acres under plow and a large number of families in the cities and villages, all of whom have a very low income and the housewife consequently has a very difficult problem to manage to provide adequately for the food, clothing, shelter and comfort for the family.⁹

The amount of property tax paid through the years revealed the new economic prosperity. The amount paid rose between 1940 and 1944. In 1940, as listed in the Department of Taxation County Schedule for Price County, ‘General County tax on property paid in cash by taxing districts’ was $94,357.34. In 1941 the same revenue source provided $103,174.81 to the county. In 1942 the community provided $157,704.27, in 1943 the amount went down slightly to $141,024.98, and finally, in December of 1944 the amount listed was $137,229.55.¹⁰

Overall Price County saw a net tax increase of $42,827.21 from the revenue taken in during the 1940 business year to the 1944 business year. This increase shows dramatic improvement from the beginning of the war to the end. A letter from the U.S. Department of Agriculture Defense Board for Wisconsin, represented by Walter F. Katterhenry, to the county board members on November 8, 1941 echoes this improvement, “The farmers of the state of Wisconsin will increase their income in 1942 approximately seventy million dollars over their income for 1941.”¹¹

Because of Butternut’s position within Ashland County, reporting the statistics for the County provides a skewed look at the actual state of the town and surrounding communities. Prosperity can accurately be seen in the number of farm improvements in the area. The 1940 Price County Assessors report found, “2747 sets of farm improvements involving an area of 6864 acres.” The total improved land in Price County amounted to 59,564 acres in 1940. Through these improvements the people of Price County enhanced their places in the world.¹²

Despite the economic hardships common before World War II the communities of Park Falls and Butternut flourished during and after the war. Every area in the country experienced an economic boom lifting them from persistent economic difficulty.

Local Organizations

Both communities felt the impact of locally run organizations. These organizations brought the community together and often provided individuals with a sense of participating in the war effort. Residents gave not only their money, but also their time to the war effort. The two biggest organizations within the communities, the Red Cross and the Auxiliary, were both women’s organizations. Because the Red Cross depended on local volunteers to go door to door and raise money, on the local level the Red Cross approached autonomy. The Auxiliary, by definition a women’s organization, focused its efforts on the community during the war. During the war years the women organized for the good of their communities and families.
The Red Cross

Within the communities no organization garnered more publicity and created a larger impact than the Red Cross. Between 1940 to 1945 in Park Falls, The Herald contained many references to the work of the Red Cross. Articles contained information on what the ladies of the Red Cross produced. One such article, September 5, 1941, contained the following, “Two shipments have been sent out recently from the club rooms of the local Red Cross... The second shipment was of woolen goods, and consisted of the following items: 19 children’s sweaters, sizes 4 to 12; 8 men’s sweaters; 15 pairs men’s socks; 10 mufflers; 6 circular shawls for ladies; and 26 skirts for girls, various sizes.” This can also be seen in the February 4, 1944 edition which contained a list of what the Red Cross shipped out, as well as asked for knitters to pick up materials to make articles such as bags, sweaters, and mufflers. As within the Park Falls area, the Butternut Red Cross conducted knitting campaigns urging women to knit articles to send to the military forces. In December of 1942 The Butternut Bulletin reported the following articles being received by the County Red Cross; “Five pairs mittens, Twenty-eight sleeveless army sweaters, Nine turtle-neck army sweaters, Eleven cardigan sweaters, Four turtle-neck navy sweaters, Seven cap mufflers, Two scarfs, Fourteen pair wristlets”.

Raising money constituted the principal activity of the Red Cross. The Herald contained many mentions of Red Cross drives, the progression, and the end result. Within the Butternut community the Red Cross maintained a presence as well. Just as in Park Falls, the main task of the Red Cross consisted of raising money for the war effort. One example is the Red Cross celebration of the North Price County Chapter for raising more than their quota on March 30, 1945. Butternut residents also gave willingly to the Red Cross drives through the war years. In December 1941 the Red Cross set the Ashland County quota at $5,002 asking Butternut to contribute $250 of that amount. Butternut met this goal, and not only reported to the county first, but also reached its goal first in the nation. As the years progressed the amount assigned to Butternut grew. In March 1943 the amount Butternut expected to raise reached $1,000. The next year, in March 1944 the amount rose again to $1,100. Each time Butternut met these amounts.

From the coverage of the Red Cross in The Butternut Bulletin it would seem the organization impacted the women of the area. The memories of women from the area contradict this assumption: only one women interviewed remembered interacting with the Red Cross. The one who did, Dixie Smart, remembers, “I was involved in that [Red Cross]. People were making things like quilt squares, blankets and bandages. Just keeping busy.” Because of her age Smart may have participated more than the other women interviewed, but no one remembered anyone in their family participating either.

Throughout the war years the Red Cross also conducted programs within the community less directly related to the war. One can be found in the January 14, 1944 The Herald. In the article the Red Cross advertised for a nutrition course at the high school. This course lasted a total of twenty hours and occurred on Tuesday evenings from seven to nine o’clock. While few details were listed, the purchase of a textbook was required, The Red Cross Standard Nutrition Text Book. Since both state and national governments showed concern for the nutrition standards of the populace, it can be assumed that diet caused great worry for government officials during the war years. Because the class was held in the evening, it was accessible to parents who worked during the days, and also a greater chance of finding a sitter for children existed during the evening.

This Red Cross course shows one of the few times a government or national organization came in direct contact with these small communities. Often, programs initiated by large organizations, such as the AAA (Agricultural Adjustment Administration), had minimal contact with the towns. Because of the rural location of Park Falls and Butternut, as well as small farm sizes, the programs and organizations often were not interested in working with them.
Many other local campaigns besides those of the Red Cross occurred during the war years. In February 1945 the Park Falls Public School held a clothing drive in association with The Save the Children Federation. In April 1945 another clothing drive occurred in association with the United National Clothing Collection for War Relief. The American Legion Auxiliary held poppy sales annually, with the May 1945 drive raising $358.49. In May 1945 the North Price County Cancer Drive also began. The article describing this drive written in The Herald included the following: “‘Guard Those You Love’ is the stirring slogan of the American Cancer Society which is launching its first major fund raising campaign for the control of cancer through the nation.”

Each time Butternut and Park Falls met their goals, even when the amount rose to problematic levels. The war allowed people the money to contribute to the many drives and donations organized in both Park Falls and Butternut. The generosity and prosperity of the communities can be seen from the success of multiple volunteer organizations in their attempts to raise money or tangible goods. The increasing economic stability showed itself by resident women’s donating money as well as their time.

*American Legion Auxiliary*

Park Falls also benefited from an active American Legion Auxiliary. This group of women focused mainly on community programs. The Herald describes one program, Child Health Center on July 7, 1944, “A Maternal and Child Health Center, sponsored by the American Legion Auxiliary, will be held in the City Hall on Thursday, July 19, from 1 to 3:30 in the afternoon. . . . This is the first Maternal and Child Health center to be held in this county this year.” Because of the female nature of the Auxiliary the center must have held personal significance. Another community centered event, a Christmas program sponsored by the Auxiliary, also enjoyed support from the legion. This jointly sponsored event consisted of musical numbers, speakers, a lunch, and bingo. The Herald recorded the highlights of the evening in the December 29, 1944 edition.

A major Auxiliary event, the sale of poppies continues to the present. The May 25, 1945 The Herald contains the history of the poppy:

>The Poppy that grew so profusely on the battlefields of Flanders is the memorial flower of those who gave their lives in the service of their country in the two World Wars, and is worn in their memory. The artificial flowers are made by veterans in hospitals and the contributions are used to finance the Service Department of the American Legion and give immediate aid to veterans who are in need.\(^{19}\)

The June 1, 1945 The Herald provided the totals for the previous poppy sale, namely $358.49. The Herald also explained the increasing need for the money raised by the poppy sales as soldiers began to return home.\(^{20}\)

The American Legion Auxiliary of Butternut also involved itself in the community during World War II. In 1941 The Butternut Bulletin reported a record year for the auxiliary in 1940. Membership reached forty-one, five more members than the previous year, and the largest membership in the group’s history. The Butternut Auxiliary also hosted a Maternal and Child Health Center, holding it earlier than Park Falls (1941 compared to 1944). Both centers were free to the public with the costs covered by the respective Auxiliaries.\(^{21}\)

During their 1942 poppy sale the Butternut Auxiliary sold every one of the 500 poppies ordered. The Auxiliary did not report to the newspaper how much money they received from the poppy sale. When asked when she joined the Auxiliary, Wegner responded, “When we were married --’cause they got Eddy [her husband] into the Legion, and he got me into the Auxiliary.”

The little communities in northern Wisconsin continuously raised large amounts of money for the war effort. As shown, this did not occur once, or even sporadically. Throughout World
War II the small communities of Park Falls and Butternut, Wisconsin raised amounts of money disproportionate to their sizes.

Food Problems and Solutions

Local organizations felt an increase in activity during the war, but the personal lives of women also felt the impact of the war. The war especially impacted women’s homemaking, especially in the kitchen. How women dealt with rationing, and sugar shortages portrays the unique qualities of the rural small town.

Stamp Plans

The food stamp program impacted women the most during the war years. Early on The Herald recognized the need for housewives and families to understand the regulations associated with the plan. In April 1941 it ran an article explaining the plan in a question and answer format. The topics covered by the article included participation, what stamps corresponded to what food, how the stamps could be purchased, where to get the food stamps, and finally, which family members could redeem the stamps.39

On July 11, 1941 The Herald ran a shorter article explaining the program more succinctly, “For each dollar’s worth of orange stamps so purchased, they will be given fifty cents worth of blue stamps free. The Federal government pays for these blue stamps with funds voted by Congress to help move the farm surplus.” Adjacent to this article ran another one aimed at area grocers and farmers. It explained why they should attend a meeting to discuss their part in the food stamp program. For The Herald to run so much information about this program within so short of a time period signifies the importance the program held for the community. On a basic level this program determined who would get what food. This affected every family in the area.24

The Butternut Bulletin, like The Herald, contained many articles explaining the food stamp programs, as well as how these programs changed through the years. The first of such articles appeared on May 1, 1941. This article provided much the same information as the first article in The Herald. An article in the February 26, 1942 issue stressed the responsibility of the homemaker, “To conserve food by proper preservation and preparation is first on the list in the patriotic call to all home makers.” The article also described how different foods should be kept or stored. The homemakers of the area already knew much of this information, but running it in the local newspaper represented how important the role of the homemaker was during the war years.25

Even half a year after the implementation of the stamp plan The Herald continued to run listings of foods on the surplus list, along with articles describing the increases in stamp sales. In December 1941 The Herald reported that sales in November increased by $3,000. The list of surplus foods for December contained the following: butter, eggs, pork, all cuts, wheat flour, whole wheat flour, corn meal, dry beans, fresh pears, fresh apples, fresh oranges, fresh grapefruit, potatoes, fresh vegetables. The items on every surplus list were similar; they included items plentiful for families that farmed even small scale. Because of the rural nature of the towns most items would not be needed by the families in Park Falls and Butternut. In fact, only the sugar shortage so affected the women that they remembered it years later in their interviews.26

The Importance of Sugar

The Herald, in the July 17, 1942 and August 7, 1942 issues echoed the difficulty in acquiring sugar. These issues included a number of recipes “To Match Your Sugar Rationing.” The recipes include Sugarless Two Egg Cake, Spice Cake, Orange Cake, Sugarless Three Egg Cake, Honey Pound Cake, Sugarless Lemon Chiffon Pie, Sugarless Honey Pumpkin Pie, Sugarless Pie Meringue, as well as recipes for sugarless spreads, beverages, and fruit punch. The ingredients
these recipes used in exchange for sugar included white corn syrup, honey, and canned sweetened condensed milk.  

Sugar shortages also created the most discussion in *The Butternut Bulletin*. The first mention of sugar rationing appeared on March 12, 1942. The article described the sugar-rationing instruction sheets that would be passed out to the rationing registration stations later in March. The article went on to describe the importance of the ration stamps. During April of the same year, an article ran expressing concern for the hotels and stores of the area in procuring sugar. The article stressed the importance of knowing how much sugar these establishments would use, “Do not feel that you can go to the high school next Tuesday or Wednesday and get this information out of your head because you can’t and the registrars who will be very busy at that time cannot take the time to help you make your estimates of the amounts which you need and which you have used and to which you are entitled.”  

The very next week, April 30, 1942, the arrangements for sugar registration appeared in *The Butternut Bulletin*. The registration of all ration books occurred, but the article stressed the registration of sugar. With the headline of this article stressing sugar, the importance of it to the populace cannot be understated. Within a short time sugar again made headlines in *The Butternut Bulletin*. On June 18, 1942, sugar for canning gained attention, much earlier than would be needed for garden canning. The article stated, “Sugar for canning purposes will be rationed to people of this community every day until further notice, by applying at the village hall between the hours of 10 and 12 in the forenoon and 1 to 4 in the afternoon.” Within a few months sugar made more frequent headlines than any other rationed good. This shows the important position sugar held in the kitchens of women in Park Falls and Butternut.  

Sugar rationing proved a significant war memory for the women interview by this author. Marion Linsmeyer responded, “Well, everything was rationed. So I did not do as much baking as I did before or after because it was hard to get sugar. We had our first baby in there sometime too. Of course, when he came along then I got another book of stamps. I could get some more sugar, and that helped a little bit. You could not make cookies or stuff without sugar. So that was nice. That wasn't the only reason it was nice to have my baby! I loved raising him.” Marge Drager agreed: “Well sugar was rationed. So you made use of that. Then my uncle and aunt in North Prairie made sorghum. That is something like molasses and they would send a big cherry tin full of that sorghum. Mom would say, 'I really don't like it but I have to use it.' Not for baking--for the fruits and that.”  

Using What You Have  

By autumn any family who gardens produces a surplus of tomatoes. On 28 August 1942 *The Herald* ran recipes explaining ways to capitalize on this abundant crop. Tomatoes earned the title of “Victory Food Special” in this issue, and recipes included fried tomatoes, baked eggs in tomato cups, as well as encouragement to eat the tomatoes raw. “On a hot day there's nothing more refreshing than cold sliced tomatoes with a sprinkling of salt. This simplest of salads gives your body two things that help it withstand the heat--Vitamin C and salt.”  

*The Herald* made an effort to urge the people of Park Falls to use easily attained foods while still providing the information needed about the food stamp program. The commitment of *The Herald* in providing up-to-date information continued in 1943 when an article describing the new Food Rationing Books ran. This article explained the difference between the previous plan and the implementation of the new one:  

The stamps in your War Ration Book Two are both numbered and lettered. The numbers designate the point value of each stamp, while the letters (A through U) designate the period the stamp is valid. The year will be divided into rationing
periods with A, B, and C valid only in the first period. The blue stamps will be used when purchasing any of the rationed items whose point value will be set by your government depending upon the supply. Your grocer will display an official Table of Point Values provided him by the government.33

This program contained far more intricacies than the previous plan. The articles explaining the new plan provided information on which food could be bought with which stamps. As in The Herald, The Butternut Bulletin ran more articles explaining the intricacies of the more complicated ration books. These articles answered questions ranging from what stamps pertained to what food to who could obtain them.33

Over the span of the war The Herald and The Butternut Bulletin devoted many articles and pages to explaining the different government-run food programs that affected the communities. The local newspapers responded to the common concern about food with extensive coverage of consumption related issues. Through looking at the newspapers and the responses of the women interviewed it appears food rationing did not create many day-to-day problems. But one item, sugar, did create many changes for the women of the communities. Sugar, because of the many ways females use it while cooking on a daily basis, represents femininity. The scarcity of this “feminine” staple explains why it would be the first instance of rationing the women remembered. Despite the challenges in obtaining the sugar necessary for running their households, the women never complained about it. Often they seemed proud to have found substitutions and to have continued running their households in as normal a way as possible. Though never boastful, these women were very proud of their ability to “make do.”34

What Did Not Happen During the War

Most studies about the homefront focus on large urban settings, or they investigate the agricultural boom. Hence, the unique nature of the small town often gets lost. Neither of the former pictures truly represent the rural small town experience during World War II. This can be seen in the small impact food rationing had upon the communities of Park Falls and Butternut.

The two primary war shortages discussed by scholars involve sugar and red meat. The comments from the women and the previously described newspaper articles show the importance of sugar shortages in the northern Wisconsin area. However, the problem obtaining red meat, or protein, did not impact the area. None of the women interviewed remembered difficulty in obtaining meat, or red meat specifically. No newspaper article save one describing an increased hunting season even mentioned meat. These women typically lived on small farms; they raised chickens and sometimes pigs, and because of this never went without meat. Wegner sums up this position, “Like the meat, we had our cows, our pigs, our chickens. Things like that. The meat never bothered us because we always had enough of what was on the farm.”35

Only Dixie Smart, who lived in Minneapolis for a portion of the war, remembered issues obtaining meat, “I didn’t have anything that I could use to buy for meat. I bought tripe. It didn’t take any points. I didn’t know what a tripe was. I thought, ‘Well, it comes out of an animal, it must be okay. I took it home and looked up in the cookbook how to cook that thing. I boiled it. It looked like a swim cap, is what it looked like. It had kind of a mottled look. I cut it up into pieces and boiled it and then I dipped it in batter and French fried it and it looked lovely but you could not eat it because your teeth would bounce right off it. What an experience.”36

Statistics such as, “By October 1943, 50 percent of all housewives could not buy as much food as they desired for their families, and only 45 percent said that the food system was working well.” do not provide an accurate picture of the lives of small town women. While sugar rationing provided an obstacle in canning, it did not prevent the women of the area from storing much of the food eaten during winter months. Drager remembers her mother doing a lot of canning for her
and her seven brothers, "Mom did a lot of canning, all through the years."37

Though the personal lives of the women were affected, the day-to-day workings of their families often were not. When asked if her family was changed by the war, Marion Russell responded, "I really would not say that it did. My family was kind of a thrifty-type of family. We had one vehicle." Excluding rationing, especially sugar rationing, no woman felt her life changed dramatically during the war. When discussing rationing, Marion Linsmeyer responded, "We did do different things. You could get a little jar of syrup once in a while. You would try that like you do in the little candy and it worked good in frosting, egg-white frosting. What do they call it? Seven-minute frosting. For that it worked pretty good."38

Only two things affected the women's lives enough to remember sixty years later, rationing and the loss of loved ones. Both of these exist on the personal level. The women of Park Falls and Butternut carried on with their lives. They dated, socialized, and helped their families. At the same time they gave time and generous amounts of money to war causes. Generally World War II did not affect the workings of the government, economy, churches or social life of the area. The limited impact of the war occurred in the area of food intake. The personal and emotional world of these women saw the biggest impact. They watched their loved ones called into duty, and sometimes die. The biggest affect of the war lives on not within the economic or social consequences of the small town, but within the hearts of the small town residents, especially the women.

Notes
4 Marge Drager, interview by author, 25 July 2005, Butternut, tape recording, private collection.
5 Marion Linsmeyer, interview by author, 26 July 2005, Butternut, tape recording, private collection.
6 Marion Russell, interview by author, 26 July 2005, Butternut, tape recording, private collection.
8 Dixie Smart, interview by author, 27 July 2005, Butternut, tape recording, private collection.
9 Price County, Clerk, Miscellaneous Papers, 1941.
10 Price County, Clerk, Department of Taxation County Schedule for Price County, 1940-1944.
11 Price County, Clerk, Miscellaneous Papers, 1941.
12 Price County, Clerk, Miscellaneous Papers, 1940.
13 The Herald (Park Falls), 4 February 1944, and 5 September 1941. The Butternut Bulletin (Butternut), 3 December 1942.
14 Park Falls Herald (Park Falls), 30 March 1945; The Butternut Bulletin (Butternut), 18 December 1941, 20 February 1942, 18 March 1943, and 24 February 1944.
15 Dixie Smart, interview by author, 27 July 2005, Butternut, tape recording, private collection.
16 The Herald (Park Falls), 14 January 1944.
17 The Herald (Park Falls), 23 February 1945, 20 April 1945, and 4 May 1945.
18 The Herald (Park Falls), 7 July 1944, and 29 December 1944.
19 The Herald (Park Falls), 35 May 1945.
20 The Herald (Park Falls), 1 June 1945.
21 The Butternut Bulletin (Butternut), 16 January 1941, and 27 November 1941.
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The Passion Narrative: A Translation and Analysis of Frederic Baraga’s Passion Narrative in Ojibwe

by

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Frederic Baraga, the early nineteenth century missionary to the Ojibwe and Ottawa peoples of northern Wisconsin and Michigan, was a talented linguist, literate in seven languages before he landed in the United States. Yet even as talented as Baraga was in languages, he still struggled in attaining fluency in the extremely difficult dialects of the Algonquian language family, Ojibwe and Ottawa. Despite his struggles, Baraga managed to master the languages after decades of study, and through his love of languages and authorship, managed to create an Ojibwe literacy movement that still resounds today. This paper reflects several years of research into this literacy movement and highlights several of the struggles that Baraga encountered in translating abstract religious doctrine into the Ojibwe language.

Irenaeus Frederic Baraga was born June 29, 1797, at Malavas, in the Austrian territory of Carniola, later known as Slovenia, to a well-to-do family. His mother died when he was eleven, and his father four years later in 1812. Frederic spent his adolescence under the tutelage of Dr. George Dolinar, a professor at the diocesan seminary at Laibach. In 1816 Baraga entered the University of Vienna, where he graduated with a law degree in 1821. Law left him unfulfilled, however, and he entered the seminary at Laibach shortly after he graduated. In September 1823, he was ordained a diocesan priest. He became an assistant at St. Martin’s parish in Lower Carniola where he was greatly loved by his parishioners.

Although Baraga was a much beloved priest, he was not immune from controversy. The Diocese of Ljubljana was not a quiet little hamlet; it was a hub of religious controversy within various religious and political factions. “Jansenism and Josephinism poisoned the air,” and it is purported that “the Bishop of Ljubljana was a Jansenist” (Jezernik, 20). Later, Baraga was sent to Smarono where his popularity quickly eclipsed that of the other priests. “Baraga was accused to the Bishop of exaggerated devotion to the Blessed Sacrament, of introducing devotion to the Sacred Heart and to the Assumption of Mary” (Jezernik, 21). Because of the conflict he was sent to become the priest of Metlika, where he soon had an even larger following of faithful Catholics. He established Metlika’s first Stations of the Cross, a devotional activity consisting of prayer at fourteen locations, each representing a stage of Jesus’ Passion and death. “The faithful were overjoyed, but this was the immediate cause of the break with his pastor and two assistants” (Jezernik, 22). At the same time Baraga experienced his first brush with authority as a result of his writings. His first book, a Slovenian prayer book Duhna pasha (Pasture of the Soul), proved very popular with Carniolan Catholics, but revealed “a spirit completely opposed to that of the regional clergy” (Jezernik, 22). During this crisis, which grew tenser as time went on, Baraga began to doubt he was fulfilling his destiny, and at this crucial point he came across a pamphlet written by the Vicar General of the Diocese of Cincinnati, Frederick Rése.

Rése was in Europe to establish a foundation for fund raising and recruitment of missionary priests to convert American Indians to the Catholic faith. He wrote a booklet that was widely
distributed and led to the creation of the *Leopoldine Stiftung* (Leopoldine Society) by the Emperor of Austria. The booklet depicted the sad spiritual state of affairs in Ohio, Michigan, and the Northwest Territories among the European settlers and the Native population. Reading the booklet changed Baraga's life, for he was drawn to stories of the Indians in the American territories. He agonized over their lack of Catholic priests and believed their souls were at risk from the Protestant proselytizers who were moving into the area. He then petitioned his Bishop for permission to become a missionary in America so he could attend to the spiritual needs of the Indians in the Territory. Baraga also approached the Leopoldine Society of Vienna for funding, which was quickly granted, and he became their first missionary to America. He left Europe knowing several languages: Greek, Slovenian, Italian, French, German, Latin, Spanish and a smattering of English. He would shortly add two others to his repertoire, Odawa and Ojibwe, dialects of the Algonquian language families.

Frederic Baraga came to the United States in January 1831. He settled briefly in Cincinnati, Ohio, and began learning the Odawa language with the help of a young interpreter, William Maccatebinessi, the son of an Odawa Indian chief from Arbre Croche (Carantha). Baraga then journeyed to Arbre Croche to fulfill his dream of bringing Christianity and literacy to the natives who resided in what is now the Upper Peninsula of Michigan. Shortly after arriving in Arbre Croche, Baraga started to write his first prayer book in the Odawa language. He was provided with an interpreter, a well-educated woman from Detroit named Angélque Campau, who spoke Odawa and several other dialects of Algonquian languages fluently. It was during this time he wrote his first prayer book in the Algonquian dialect of Odawa. This work is an excellent example of his proclivity for languages; although he was by no means fluent at this time, he believed he had learned Odawa well enough to write a 205 page religious text filled with Christian prayers, hymns, stories and explanations of abstract concepts entirely in the Odawa language. In a letter to the Leopoldine Society on December 17, 1832 Baraga wrote:

> The Indians consider themselves fortunate that they now have a prayer book, which at the same time includes a rather extensive catechism, in their own language. The prayer book which they formerly had, my predecessor has had printed last year after an Algonquian manuscript which was full of clerical errors; and because, although the Algonquin language which is spoken by the Indians of Montreal, Canada, is related to the Ottawa language, there are, nevertheless, very many words in that language that are entirely unintelligible to the Ottawa nations. And so, in their former prayer book very much appeared that no Ottawa understood at all. Therefore, these good Ottawa Indians are extremely happy over their new prayer book, which as they say, speaks exactly as they do. They have it almost always in their hands and learn it by heart. Especially the school children, who already can read, learn their rather long daily lessons from the catechism so accurately by heart that it often amazes me.

Baraga spent several more years in Michigan, establishing a mission at Grand River, where he stayed until February 1835. He then moved to La Pointe (now Wisconsin) in July of 1835 and stayed there until 1843. During this time, Baraga was especially prolific in creating new and updated prayer books, catechisms, collections of Bible stories, and similar works. By the end of 1835 Baraga believed himself fluent enough in the Odawa language to dispense with an interpreter. In a letter to Bishop Rése he wrote:

> October 12th – I must close, however, with joyful news. This is, that I have cast off entirely and forever the oppressing yoke of [an Odawa] interpreter, and finally attained independence, which makes me not less triumphant than the Americans independence make Americans triumphant. A few weeks ago I
myself began to teach the Indians, and it works very well. After I had made my first attempts to give the lessons myself, the Indians, have, to my very great consolation, sent a messenger to me with the request to always teach them by myself without an interpreter; which, since then, to my greatest delight, I have and always will do. – For the last two weeks I am working on the translation of the Ottawa prayer book into Chippewa, and with your assistance, I shall endeavor to have this Chippewa book printed next spring in Detroit for the benefit of my mission and of Father Haetscher’s mission. For this work I avail myself of a real Saulteux, the son of Michael Cadotte. The work progresses very well. At the time I am writing this to you, I have already translated three-fourths of the Ottawa payer book into Chippewa. I hope to complete it in 5 days. I will enlarge and improve the catechism a little. Through the entire winter I will have time to often look over the book and correct any errors that may be in it. The difference between the Ottawa and Chippewa is not insignificant. My assistant translator does not understand very many of the words in Ottawa; fortunately, I understand them and tell them to him in French, whereupon he gives them to me in Chippewa.

In 1837, Baraga restructured his Odawa version of his prayer book and also wrote his first Ojibwe translation of the same, both of which were well received. Although in a letter to the Leopoldine Society Baraga states “...in regards to the language I must remark that it deviates only slightly from the Odawa language” (Ceglar, 28), later he wrote to Bishop Rèse, “They, [the books] were printed in two dialects, Ottawa and Otchipwe, which required a lot of changing and extra work” (Ceglar, 29). In a different letter, written on December 28, 1835, to the Leopoldine Society, Baraga writes:

In regards to the language, manners and customs of the local Indians, I must remark that the language of these Indians deviates only slightly from the Odawa language. At first I believed that the difference was greater because the accent misled me. But now I see that it is trivial. These Indians understand me very easily and they have great satisfaction in hearing the religious instruction directly from the mouth of a priest. Even the children are anxious to listen to religious instruction and to learn the catechism by heart, which I repeatedly recite to them until they retain it and they need not be first driven to it.

Baraga’s preface to his Ojibwe readers states why he wrote these books in both dialects: “My Children, This book (is written) just as you speak (in your language) so that you may understand correctly. Frederic Baraga, Black Robe” (1849, 4). Although he considered the differences between Odawa and Ojibwe minor, it was important to him that his parishioners completely understood the Christian doctrine in their own language.

Baraga found himself in the middle of controversy again with his creation of the 1837 Prayer Book. His translation of Christian concepts into Ojibwe and Odawa was not without its share of problems. Abstract concepts are difficult to translate, and Baraga probably relied on helpers’ opinions on how to convey Christian messages. At the end of January 1837, Baraga arrived in Europe to have his book printed and bound. During this trip, he learned that an expert on the Algonquian language, a Sulpician priest named Father Thavenet, was in Rome (Jezernik, 67). Thavenet had worked mainly at the Oka Mission in Canada between 1793 and 1815, before returning to Rome (Morice, 381). Baraga requested a visit with the old missionary for a critique of his Anamie-Misinatigan. Thavenet was curious as to how Bishop Rèse could have approved Baraga’s translations when Rèse did not know the Algonquian language. Baraga informed him that he himself had told the Bishop what the translation meant. This must have peaked Thavenet’s interest,
for he took a close look at what Baraga had written and his analysis was highly critical.

The following day Thavenet examined the catechism. He did not find it of much account. "I found it badly done, but I did not say this to him. There was one real error, in the words he used to express the difficult concept of Transubstantiation. Speaking of the Transubstantiation, he says that the Body of Jesus Christ is changed into bread and Blood is changed into wine." Thavenet wrote out a new Indian text, right after Baraga's original phrase; the catechism, as it is in the Archives, bears this one correction only, about the Transubstantiation. "In regard to all I noticed in the catechism, I think it is useless to send a detailed account to him, and even more useless to put it before the eyes of Your Eminence. I will only say, Monsignor, that there are many inaccuracies, many questions and answers poorly handled, superficial terms and even omissions of essential points, many inappropriate expressions, phrases and propositions." (Jezernik, 68-69)

Baraga took Thavenet's criticisms to heart, though there may be some doubt as to just how well Thavenet knew Odawa as opposed to the different dialect of the Algonquian language he had learned in Canada. True, he had worked for 22 years among the Canadian Algonquian and was considered fluent in the Algonquian language. However, when Baraga and Thavenet conversed in it, Thavenet later wrote his account of the meeting: "You speak it far more fluently than I do, who has not spoken it for over thirty years and only remember the theory; however I would like to point out to you that you have used a word which does not really express what you mean and I showed him the root of a word which truly expressed his idea" (Jezernik, 68). Baraga agreed to have his books changed to reflect the correct concepts, even though he had already had the books printed, though not bound. Before he left the Continent, he had corrected his texts and had them bound back in America.

Baraga may have accepted Thavenet's criticisms of his texts, but later, when the Vatican Congregation de Propaganda Fide decreed that all of his (as well as other missionaries') translations must be re-translated word-for-word into Latin, and then sent to Rome for review before printing, he balked:

That which Propaganda asks of all the missionaries amongst the Indians surprises me greatly. How is it that this venerable and wise Congregation can do something so ill-advised? M. Thavenet believes me to be a heretic and has influenced them to give this order...Thus I find myself in a collision of duties; on one side my duties of state which, in conscience I judge all important, on the other side the duty Propaganda imposes on me of making this translation which, I judge, in conscience, useless...I cannot do otherwise than decide in favor of my duties as a missionary to the Indians as being more important than the duty to translate my Indian books; another person, less busy than I am, could do this if, of course he knew the Indian language; if he does not, then he cannot be a competent judge of the case. (Jezernik, 78-79)

Baraga felt that the work this decree proposed was unacceptable and soon the matter was dropped. Research has shown that Baraga did not submit any of his later works to Rome in Latin for review.

In each area Baraga called home, his first priority was to erect a church, which in many cases also doubled as a school. In Baraga's school students were taught to read and write their language. This contrasted with early Protestant missionaries who dismissed the students' native language and taught exclusively in English. Educating Indians in their native language began only after seeing Baraga's success with his students. In fact, much contention existed throughout Ojibwe territory between Father Baraga's educational program and that of the Protestant missionaries. In
a letter to Bishop P.P. Lefevere he revealed his frustration with the Federal Government, an entity that preferred to give money to the Protestant missionaries, and where “doubts of the propriety of a portion of the school fund being allowed for the support of Catholic schools” existed (Baraga, 1843). Baraga believed in his heart that the Catholic Missions were more effective than those of the Protestants, even if the Protestants had more schools. He observed, “The Protestants have the means to give greater éclat to their education of Indian children then we... they take the little Indians into their families, or in their boarding houses, and teach them to speak English.” This was a source of frustration for Baraga as he saw the teaching of English to Indians as a government directive, not something that was in the best interest of the Ojibwe. In fact, he states: “The Americans are pleased with Indians who speak English,”(Baraga, 1843) which was contrary to Baraga’s main scholastic goal of educating the inhabitants of the missions in their own language. He felt it was up to the visitors who came to Anishinaabe land to learn the native language, not the other way around. Baraga had “the satisfaction of finding real, hidden beauty in the Indian language” (Jezernik, 54).

Baraga was caught between educating Indians in their own language—and thereby keeping it alive—or giving English teaching a higher priority in order to make Indians more acceptable to Americans. He believed in the importance of the natives being literate in their own language, and through his schools, prayer books, and catechisms, many Ojibwe and Odawa Indians learned to read and write in their own language, thereby starting a literacy movement that continues today. In a letter to Bishop P.P. Lefevere, Baraga wrote regarding his school in L’Anse:

I have also established a Catholic school here... Our school consists of 51 pupils, that is to say of 20 boys and 3 men, and of 19 girls and 9 women. At first they are taught to read and also catechism; later they will be taught also to write and figure; all of this in their own language. Some of these pupils make astonishing progress. In two months’ time they have learned to read from the prayer books which you have had bound for me this summer. It is true that they do not read passably as yet, but within a short time they will read fluently.

Ojibwe literacy was strong, thriving, and growing, at least until the United States Government, through the boarding school era of the late 19th century, enforced an English-only curriculum on American Indians, forcing assimilation upon them, and in the process denying them their culture and language.

Baraga continued to refine and revise his religious works, printing several books in both languages (Appendix I). His later books were written solely in Ojibwe, and his last book in 1865 was the final text of a prolific thirty-year career of literacy. Each subsequent edition shows the increasing refinement of Baraga’s understanding of both languages, his struggles with translating abstract concepts into the native languages, and the perfecting of his grammar, spelling and syntax in the Ojibwe language.

Before undertaking an analysis of specific terminology, one must first outline, for a general layman’s understanding, some of the fundamentals of the Ojibwe language. Ojibwe is a morphologically rich, heavily verb-based language. One word, with the inflections added as prefixes and suffixes, can encompass an entire sentence in English. Ojibwe words start with a core word and inflections, based on the grammatical category of the core word, are added to further specify and define the meaning. For example, in English one would add a morpheme to the word realistic and change the meaning by adding the prefix un- to make a completely different word, unrealistic. What Ojibwe does is exactly this, although on a much more sophisticated and complex level. As stated earlier, Ojibwe is a verb-based language, with over 80% of the words in its lexicon being verbs. Nouns are either animate or inanimate and depending on this categorization an appropriate verb must match the noun in a sentence. There are several categories of verbs, but for the purposes
of this discussion, only four will be cited. A VTA, or verb transitive animate, must be paired with an animate subject and an animate object [someone (animate) did action to someone (animate) object] (Nichols and Nyholm, xviii). For example, gibakite’oon (I hit you) is an example of a VTA. A VTI, or verb transitive inanimate, must be paired with an animate subject and an inanimate object [someone (animate) did action to something (inanimate) object] (Nichols and Nyholm, xvii). For example, nimbiinitoon (I clean it) is an example of a VTI. A VAI is a verb with an animate subject and no object [someone (animate) did action - no object] (Nichols and Nyholm, xv). For example, giitagoshin (she arrived) is an example of a VAI. The fourth type of verb is the VII or verb inanimate intransitive. This verb has an inanimate subject but no object [something did action (inanimate) no object] (Nichols and Nyholm, xvii). For example, ishpaa (it’s high) is a VII verb.

This research project focused primarily on the Passion Narrative in the 1837 text, Jesus O Bimadisiwin Oma Aking (A Life of Jesus Here on Earth). The Passion Narrative is the retelling of Jesus’ last days. Baraga started the episode with Jesus’ anointing with precious oil by Mary Magdalene and then his final interactions with his disciples at the Last Supper. He concludes the drama with the arrest and beating, crucifixion and burial of Jesus Christ. The Passion Narrative was a theme that strongly attracted Baraga from the beginning of his religious career, as one notes from his earliest writings and the names of missions that he founded in the Northwestern Territories. Because this topic is central to Catholic doctrine, it is one of the best examples of Baraga’s understanding of the language he was writing in.

Translating documents, narratives and oral stories into any language is a difficult task, especially when one is working to learn and perfect that language. Add to this the fact that Ojibwe is a complex language that takes a lifetime to master, and it is inevitable that there will be examples of Baraga’s struggles to translate and publish his texts in Ojibwe. In looking at several of these struggles, one sees that despite Baraga’s claims of fluency in Ojibwe in 1837, he was still learning its semantics and syntax. Added to these difficulties, Baraga still struggled with maintaining official Catholic dogma while translating these concepts into words that his converts could relate to and understand.

One of these translations is the word, ganiganikikendamogobanenag which Baraga uses to mean “prophet.” According to the Oxford English Dictionary, the meaning for “prophet” is a person who speaks by divine inspiration through whom the will of a god is expressed; one who predicts or foretells what is going to happen (OED def. I. 1. a., II.5.a.). In comparison, Baraga’s dictionary for “prophet” shows the following:

**ga-niganikikendang:** prophet (BE, 201)
**ga-niganikikendang:** He who knew the future, a prophet (BO, 122)

Baraga’s entry looks comparable to the Oxford English Dictionary’s. However, it appears that Baraga created a noun out of a verb to satisfy a Catholic definition of *prophet.* In itself, this is not a problem. Because of the morphology of Ojibwe, creating new words out of core verbs is easy and commonplace. As shown below, Baraga created the noun for prophet out of a VTI verb, kikendan (I know it, I am aware of it, I experience it) to create ga-niganikikendamogobanenag (BO, 187).

**nigan** – adv – ahead, before, in advance, in the forepart, beforehand (BO, 286)
**kikendan** – vti – I know it, I am aware of it, I experience it (BO, 187)
**ga** – past tense in participle form
**-gobanenag** – 3rd person, participle, dubitative (doubt), pluperfect

Baraga, following the syntax of Ojibwe, knew that if he combined all of the specific suffixes and prefixes, he could create a noun that would satisfy the Christian concept of “prophet” or literally, “Those, from long ago, who knew something beforehand.” His construction would also have satisfied the constraints of the Church. Baraga’s Ojibwe word, however, could mean anyone who lived long ago who had some knowledge that others did not; that knowledge would not necessarily be
religious. Interestingly, a word already existed in Ojibwe that meant something similar but carried dangerous connotations from the perspective of the Catholic religion – *jiisakiwinini*. *Jiisakiwinini*, an animate noun, means a seer or prophet who uses a shaking tent and knows something beforehand or has ways to find answers for those who need them. However, Baraga's avoidance of this word for Old Testament prophets is telling.

Shaking tent divination is conducted by prophets who specialize in divination between the living, the dead, and all of the *manitos* (spirits). Traditionally the *jiisakiwinini* served as conduit for an audience to speak to the spirits. An individual would request a shaking tent ceremony when hoping to recover lost objects, to request spiritual or practical help from the *manitos*, or to ask for a prediction. The *jiisakiwinini*, tied to a pole in the center of a wigwam, would pose questions to the spirits. The audience, sitting outside the tent, would hear the conversation while watching the wigwam shake from the visiting spirits. To the Anishinabeg, the *jiisakiwinini* was a true prophet, but Baraga's avoidance of a word they already knew as prophet and religious speaker suggests a misalignment with Catholic doctrine and decree.

The goal of Catholic missionaries sent to the Americas was to convert Indians from their pagan religions and make them strong Catholic parishioners. In their Eurocentric vision, Indians were not acculturated until they accepted European values, including religious ones. Therefore, Baraga constructed a word that meant prophet in Ojibwe, but sidestepped what Rome considered a pagan practice. He avoided thereby charges of heresy.

Ganiganikikendamogobaneag provides an excellent example of how Baraga used the semantical and syntactical properties of a language to change the thought process of a culture and create a mindset of Catholic proprieties in the Native population. In *matchigijwe* (to blaspheme) (180,6), a word Baraga used twice in the Jesus O Bimadisiwin Oma Aking text, one finds another example of Baraga’s deliberate construction of an Ojibwe word to avoid the pagan association attached to a preexisting synonym. According to the Oxford English Dictionary, blaspheme means “To utter obscene or impious words, talk profanely, or to speak irreverently of, utter impiety against (God or anything sacred.)” (OED def. 1, 2). In comparison, Baraga’s dictionary for “blaspheme” shows the following:

*nin matchigijwe*: blaspheme (BE, 30)
*matchi*: bad, evil, ill, wicked, malignant, malicious, mean, vicious, unfit (BO, 226)
*gijwe*: I talk, I speak (BO, 133)
*kitchi*: adv - can be used to intensify the meaning – “greatest of bad speech” (BO, 193)

In the Ojibwe part of the dictionary no exact definition exists for *matchigijwe*, instead one must look up the preverb *matchi* and then the word for speak, or *gijwe*. Most of the words used in Ojibwe texts require one to look up core words and prefixes. However, this one is puzzling because Baraga included a word that means “I speak sinful wicked words; I blaspheme,” *bata-gijwe* (BO, 70) in the Ojibwe section of the dictionary. A search of the entire Jesus O Bimadisiwin text reveals just two instances of *matchigijwe*. Both occur in the account of Jesus’ arrest and presentation to Caiphas for questioning:

6. – *Iwapi dach maiamawi-niganisid pagitchigewinningi obigobidon*9
*obabinsikawagan*, ekiting: Gikitchi
*machti* *jiisakiwinini; anin enabadisiwad baiaitangedig*? 7. Ki ginondam kitchi
*machti-gijwewin*.

Nowhere else in Jesus O Bimadisiwin, or the 1837 Anamie Masinaigan does one encounter the words

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matchigijwe or batâ-gijwe. In the Passion Narrative of 1850, Katolik Enamiad, which is a publication of Catholic Religious Doctrine, and describes the Bible to Catholic Christians, one finds only two instances of the term matchigijwe and both refer to the accusation concerning Jesus’ blasphemy. Possibly Baraga wanted here to delineate between an ordinary sinner’s blasphemy and Jesus’ unique and ironic situation. A more in-depth analysis and translation of the entire text—the next logical phase of this research—may reveal why Baraga chose to use matchigijwe rather than the more specific and common batâ-gijwe.

A third example of Baraga’s translation complexity lay with his choice of noun for Jesus’ disciples. In most of the 1837 text Baraga used the change conjunct of anoki (enonadjin) for the twelve disciples. For example, on page 169, line 2, Baraga wrote: “Oginan sa enonadjin: Ki kikendam, njogwanagak Paque tchi odjitchiseg” which when translated means, “He said to his disciples: You know in two days it is Passover and it will come to pass that the Son of Man will be sacrificed, nailed to the cross.” Enonadjin is actually the participle of anona which means ‘I hire or employ him, to do me some service or work; p. enonad” (BO, 41). In the context of the above sentence, Baraga is using enonadjin to mean disciples when in practical, daily Ojibwe the meaning is much different—literally an employee—a rather pedestrian word for the twelve followers of the Son of God. In fact, enonadjin rather than kikinoamagan is the word of choice throughout the entire Passion Narrative for disciples. In the 1850 Katolik Enamiad, however, Baraga used kikinoamagan for disciples rather than enonadjin. Sometime over the thirteen years between books, Baraga refined his choice of words; his own dictionary does list a specific word for disciple—kikinoamagan (BE 74, BO 188), but because the dictionary appeared many years after his first books, one cannot determine whether Baraga simply utilized a close word (enonadjin) to mean disciples until he possessed a more complete grasp of the semantics of Ojibwe.

In another example, the story of Judas and the thirty pieces of silver, one encounters Baraga’s incomplete grasp of Ojibwe spelling (p. 170): “9. Odinawan dach: ’Nissimidana dasswabik jonia ki gaminigo.’ 9. And they said to him: ‘You will be given thirty pieces of silver.’” In Ojibwe combining items involves redundancy for emphasis. For example, nissimdana means thirty (BO 303), whereas dasswabik denotes so many objects of metal, stone or glass (in numbers over nineteen) (BO, 104). Jonia, or rather jonia, means money or silver (pieces) (BO 176). The difference in spelling indicates that in 1837 Baraga possessed only an incomplete grasp of the spelling of Ojibwe; he used the same spelling in a later passages, specifically on page 183, whereas in his 1850 Katolik Enamiad, he spelled jonia correctly.

Other words used in Jesus O Bimadisiwin suggest Baraga’s poor creation of words and suffixes as these do not seem to grammatically match the core word. For example, on page 179, Baraga used the word awa-, a VTA meaning “I make use of some animate object” (BO, 56). Baraga employed this in sentence six, “Anauui nibiwa atsiminawighkidjid pindegox wi utaninds, ka dach gego awasinon ekitowad” (179,6), which translated means, “Indeed, many liars entered to accuse him but nothing that they said could be used.” Notably, the VTA awa- has an incorrect ending; instead, it required -sinon, a VII ind neg o, op ending.

A further point of interest is Baraga’s compilation of the Passion Narrative. It is unclear exactly which religious models Baraga made use of while composing Jesus O Bimadisiwin, or if he used any at all. For example, the Passion Narrative is not a full translation of one specific gospel, but rather a blending of all four books from the Synoptic Gospels (Matthew, Mark, Luke and John). Baraga possibly used a contemporary concordance as an outline to his writings. It is also possible that Baraga created his own Gospel model, although no writings of this sort have survived. A final possibility is that Baraga composed the Passion Narrative in his own manner as he translated it into Ojibwe. This possibility draws strength from an analysis of the Passion Narrative’s content, drawn mostly out of the passages from Matthew, although several passages from John and Luke.
also appear. The skill with which Baraga blended these is apparent:

(Luke 22:43-44) 7. He was suffering greatly, he prayed a lot more, his sweat looked like it was blood dripping onto the earth. 8. God’s angel appeared from heaven and he gave him strength. (Matthew 26:45) 9. And again he approached the disciples and said: “Sleep and rest today, it is already the hour when the Son of Man will be betrayed into the hands of the sinners.”

This insertion of Matthew into what up until then had been a full passage of the Gospel of Luke shows that Baraga was putting a lot of thought into his Passion Narrative. However, in the same passage, a side-by-side comparison shows subtle differences in wording between the actual text and Baraga’s rendition:

(Luke 22:43-44) 7. He was suffering greatly, he prayed a lot more, his sweat looked like it was blood dripping onto the earth. 8. God’s angel appeared from heaven and he gave him strength. (Luke 22:43-44) And there appeared to him an angel from heaven, strengthening him. And being in an agony he prayed more earnestly; and his sweat became like great drops of blood falling down upon the ground.

This supports the idea that Baraga created his rendition of Jesus’ suffering by freely utilizing the Synoptic Gospels, rather than any specific textual model. However, until additional documentation or analysis supports this theory, one cannot be sure.

Each of the above examples, taken individually mean little more than that Baraga may have simply sharpened his language skills over the years—a reasonable expectation in light of Ojibwe’s complexity. However, when one considers all of the words that Baraga changed, it appears more probable that as he gained fluency, he needed to find more appropriate words to express the religious doctrine he expounded in his text. In addition, Baraga’s use of translators during his early years complicates things further: one assumes that the translators were fluent in both Ojibwe and French or English, but this is unknown. Those whom Baraga employed may have had varying degrees of proficiency although no known documents that address this, other than Baraga’s own letters and his diary, support or refute the use of translators.

Frederic Baraga, the early nineteenth century missionary to the Ojibwe and Ottawa peoples of northern Wisconsin and Michigan, was a talented linguist, literate in seven languages before he landed in the United States. Yet even as talented as Baraga was in languages, he still struggled in attaining fluency in the extremely difficult dialects of the Algonquian language family, Ojibwe and Ottawa. Despite his struggles, Baraga managed after decades of study to master the languages, and through his love of languages and authorship, managed to create an Ojibwe literacy movement that endures today.

Appendix I

Works by Frederic Baraga in Odawa and Ojibwe (Compiled from Ceglar)

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### A Translation and Analysis of Frederic Baraga’s Passion Narrative in Ojibwe

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### Notes

1 Thavenet may have inadvertently stated thirty years; research shows that the latest he was among the Algonquians was in 1815, just over twenty years earlier.

2 See *bigobidon* – see “tear” in BE

3 Cf *bisikagan*

4 Literally, “he has spoken the greatest of bad speech”

5 Matthew 26:12, 27:64.

6 John 13:12-13, 18:15, 19:25-27


8 According to Ceglar, “it is not known whether any prayer book from 1848 ever existed. The only mention of it is in Richard R. Elliott’s article on Father Baraga’s books in the Indian language” (Ceglar, 41).

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Getting Both Sides of the Story: Sexual Attraction and Events Between Young Adult Cross-Sex Friends

by

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Department of Psychology

Abstract

Debate exists on the degree to which cross-sex friends experience sexual attraction to one another. The few studies that address this debate fail to consider the reports of both members of cross-sex friendship pairs regarding their perceptions. In the current study, 89 pairs of young adult cross-sex friends reported on their friendship. Men more frequently reported sexual attraction to their friends than did women, along with a stronger desire to date their friends. This proved true even after controlling for men's greater sexual unrestrictedness. Men overestimated, and women underestimated, their friend's attraction to them. Approximately 25% of friendship pairs had romantically kissed, and over 10% had "fooled around." For both sexes, attraction to a friend and desire to date a friend were not associated with friendship duration; this suggests that attraction to friends is not necessarily overcome with time.

Introduction

Hit American movies such as *When Harry Met Sally* and *Just Friends*, along with sitcoms such as *Friends* and *Seinfeld*, seem designed to convince us that cross-sex friendships are not always entirely platonic. Indeed, these media have been chastised for just that reason (Chatterjee, 2001; Hoggard, 2006). Yet existing research agrees with modern media. In one study, for example, 62% of adults reported that they experienced sexual tension in their cross-sex friendships (Sapadin, 1988); in another, 58% of young adults reported at least slight sexual attraction to a specific cross-sex friend (Kaplan & Keys, 1997). In yet another, 51% of college students reported having sex with at least one cross-sex friend at some point in their life (Afifi & Faulkner, 2000). These findings suggest that young men and women often have a difficult time being “just friends.” What is so unique about friends of the opposite sex?

Friendship is defined as a relationship of voluntary companionship and emotional support, generally between individuals who are not genetically related (Fehr, 1996). Prior to adolescence, girls and boys are not inclined to forge friendships with one another (Werking, 1997). Moreover, friendships between men and women – in young and middle adulthood – appear to be a twentieth century phenomenon (Monsour, 1996). In the past few decades young men and women in industrialized nations appear increasingly to engage in activities together, outside of the realm of marriage or reproductive unions. It is now common, for example, for men and women to work, play sports, and pursue vocational training and hobbies together. Viewed from an evolutionary perspective, the emergence of purposeful friendships between reproductive-aged individuals of the opposite sex is intriguing. In all likelihood, men's and women's evolved mating strategies (e.g., see Buss & Schmitt, 1993; Gangestad & Simpson, 2000) are activated in the reproductively viable but genetically unrelated company of members of the opposite sex. If men's and women's mating strategies do become activated in cross-sex friendships, then it follows that: (1) men and women should
perceive opposite-sex friendships, to some degree as opportunities for acquiring a romantic partner; and (2) given men’s stronger evolved desire for casual sex (Buss & Schmitt, 1993; Ellis & Symons, 1990), men should experience more sexual attraction to their friends than should women.

Substantial evidence exists to support these predictions. For example, in her study of undergraduates, Reeder (2000) found that although nearly all cross-sex friends felt close and connected to each other as friends, 14 percent of the pairs also wanted to turn the friendship into a romantic relationship. Furthermore, single women more than involved ones, and men regardless of their relationship status, judged the romantic potential in cross-sex friendship (i.e., a desire to date the person) as an important reason for initiating such a friendship (Bleske-Rechek & Buss, 2001).

Evidence also supports the prediction that men will experience more sexual attraction to their friends than women will. Men evaluated the potential for having sex with a close cross-sex friend as more beneficial than did women; they were also more likely than women to report having had sex with a friend who was attracted to them (Bleske & Buss, 2000). Compared to women, men judged sexual attraction and the desire for sex as more important reasons for initiating a cross-sex friendship; they reported greater levels of sexual attraction to their cross-sex friends, and judged the loss of sexual attraction to their cross-sex friend as a more important reason for dissolving the friendship (Bleske-Rechek & Buss, 2001). These sex differences are consistently large in magnitude. Furthermore, involvement in a romantic relationship did not seem to moderate men’s attraction to their friends: in both college and community samples, single and involved men reported similar levels of sexual attraction to their cross-sex friends (Bleske-Rechek & Buss, 2001).

While illuminating, the existing research devoted to the topic of attraction in cross-sex friendship is nonetheless limited. First, most studies do not include both sides of the story, that is, reports from both members of the friendship pairs (see Werking, 1997, for an exception). Although participants in previous studies reported on platonic friends of the opposite sex who were neither dating partners nor family members (e.g., Bleske & Buss, 2000), it is possible that the robust sex difference in attraction could have resulted from men’s and women’s envisioning a different “type” of friend when asked to report on a cross-sex friend. The current study, therefore, systematically surveys both members of the friendship.

A second limitation of past research concerns the possibility that women’s lower level of attraction is a function of socially desirable responding. Perhaps women in past studies unconsciously deceived themselves about attraction to their cross-sex friends or consciously attempted to leave a favorable impression of themselves and their sexuality. Thus, the current research employs a measure of response distortion, the Balanced Inventory of Desirable Responding-Version 6 (BIDR-6; Paulhus, 1991).

Third, past research on sexual attraction in friendship overlooked men’s higher levels of sexual unrestrictedness as compared to women’s (Simpson & Gangestad, 1991). Perhaps men are more sexually attracted to their cross-sex friends than women are, and hence experience more sexual desire in cross-sex friendships, because they begin with a greater interest in and willingness to engage in opportunistic sex. Such a “bias” toward one’s cross-sex friends would surely facilitate the pursuit of a short-term mating strategy. To assess this possibility, the current study includes sexual unrestrictedness as a covariate when investigating sex differences in attraction.

Finally, while one study has investigated the frequency with which individuals engaged in a sex act within the context of cross-sex friendship (Affifi & Faulkner, 2000), none has attempted to chart the progress of friendships as they undergo such events. This study cross-checks the reports of both members of the friendship pair as to whether various sexual acts occurred between them, when these happened, and under what circumstances.
Method
Participants
A total of 89 pairs of opposite-sex friends from a regional, public university participated. Friendships ranged in duration from 2 weeks to 17 years, with the typical friendship averaging 2 years. Half of the participants were first-year students enrolled in a general psychology course, and the other half were their friends. The psychology students received credit toward their course grade for participating. The majority of participants were Caucasian.

Measures
Participants completed the 40-item BIIDR-6 as part of a larger questionnaire (Paulhus, 1991; Paulhus & Reid, 1991). Twenty items on this inventory measured self-deception, or the tendency to give unconsciously inflated self-descriptions. Sample self-deception items included “I never regret my decisions,” and “My first impressions of other people usually turn out to be right.” Another 20 items measured impression management, or the tendency to give consciously inflated self-descriptions. Sample impression management items included “I always obey laws, even if I'm unlikely to get caught,” and “I never cover up my mistakes.” Following previous research (e.g., Meston, Heiman, Trapnell, & Paulhus, 1998), the study employed a seven-point Likert-type rating scale (1 = Not true, to 7 = Very true), reverse-scoring of negatively keyed items, and counting one point toward each extreme response (a response of 6 or 7; all other responses counted as 0). Total scores on each scale ranged from 0 to 20.

Participants also completed the Sociosexual Orientation Inventory (SOI; Simpson & Gangestad, 1991) that measures individual differences in attitudes toward casual sex and behavioral experience with casual sex. The SOI includes three attitudinal items (e.g., “I can imagine myself being comfortable and enjoying ‘casual’ sex with different partners”), rated on a nine-point Likert-type scale (1 = I strongly disagree, to 9 = I strongly agree). Another four items are behavioral (e.g., “With how many different partners have you had sex within the past year?”); we did not score one of these items, which assesses frequency of extra-pair sexual fantasy, because the majority of our single participants did not answer it. Thus, we computed a six-item composite score according to the weighted conventions offered by Simpson and Gangestad (1991). Higher scores on the SOI represented greater sexual unrestrictedness, or greater willingness to engage in casual sex.

Later in the questionnaire participants reported how physically and sexually attractive they found their friend, and estimated how physically and sexually attractive their friend found them. These ratings were made on a nine-point Likert-type rating scale (1 = Not at all attracted, to 9 = Extremely attracted). Because physical and sexual attraction ratings highly correlated (self $\alpha = .94$, friend $\alpha = .90$), these were averaged for all analyses reported below. On a similar nine-point scale (1 = Definitely not, 9 = Definitely yes), participants reported their desire to romantically date their friend, and estimated their friend’s desire to romantically date them. Finally, participants reported whether they or their friend had ever told one another that they were attracted to the other, whether they had ever engaged in romantic kissing, whether they had ever “fooled around,” and whether they had ever had sexual intercourse. For each act that did occur, participants reported how long they had been friends at its occurrence. For kissing, fooling around, and intercourse, participants also reported whether they were intoxicated at its occurrence.

At two separate points in the questionnaire, participants were asked (in slightly different terms) whether they were currently involved romantically with the friend with whom they had attended the session that day. No participant responded positively to either of these questions.

Procedure
Participants were instructed to bring to the session an opposite-sex friend who was neither
a family member nor a romantic partner. Upon their arrival, friendship pairs completed consent forms. Then, to ensure that friends were not influenced by each other’s presence, a male researcher escorted male participants to a separate classroom. Thus, although everyone completed the same questionnaire, men and women completed theirs in separate rooms. Participants placed their completed questionnaires in sealed boxes, and were debriefed in writing. The entire procedure took approximately 45 minutes.

Results

Table 1 displays descriptive statistics, by gender, for SOI scores, attraction ratings, and desire to date ratings. Similar to samples from previous research (e.g., Simpson & Gangestad, 1991), SOI scores (male $\alpha = .82$, female $\alpha = .88$) were positively skewed for both men and women. Although men’s SOI scores were somewhat higher than women’s, the former were less variable than the latter. For all analyses below, men’s and women’s reports were considered paired data.

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<td>Estimate of Friend’s Desire to Date Self</td>
<td>4.79 (2.00)</td>
<td>4.28 (2.29)</td>
<td>2.05</td>
<td>.04</td>
<td>.44</td>
</tr>
</tbody>
</table>

Attraction to Friend

Gender and Sociosexual Orientation. As illustrated in Table 1, men reported higher levels of attraction to their friends than women did; this effect was of moderate strength. On the given scale of 1 (Not at all attracted) to 9 (Extremely attracted), the median sexual attraction score for men was 6 and for women 3.5. The modal response for men was 7, and for women 1. More sexually unrestricted men reported more sexual attraction to their friends [r(86) = .22, p < .05], whereas sociosexual orientation was not linked to women’s reported level of attraction to their friend [r(87) = .04, p = .69]. The gender difference in attraction, however, was not a product of men’s greater sexual unrestrictedness; men’s higher level of attraction compared to women’s did not vary in magnitude at varying levels of sociosexual orientation [repeated measures interaction F(1, 85) = .84, p = .36].

The first panel of Figure 1 shows men’s and women’s self-reported attraction to their friends, while the next two panels display a comparison of those self-reports with men’s and women’s estimates of their friends’ attraction to them. As displayed in the second panel of Figure 1, men overestimated their friends’ level of attraction to them [men’s estimate vs. women’s self-report, t(86) = 2.23, p < .05, d = .24]. As displayed in the third panel, women underestimated their friends’ level of attraction to them [women’s estimate vs. men’s self-report, t(86) = 2.87, p < .01, d = .31].

Socially Desirable Responding. To test for the possibility that women report lower levels of attraction to their friend because they are unconsciously self-deceiving or consciously engaging in impression management, we compared men’s and women’s BIDR-6 scores, and then within each gender investigated associations between socially desirable responding and degree of reported attraction. Men’s self-deceptive enhancement scores (M = 5.89, SD = 4.43) were higher than women’s [(M = 4.61, SD = 2.19), t(86) = -2.41, p < .05, d = .26]; but the sexes were similar in their impression
management scores [(male M = 5.36, SD = 3.27; female M = 4.96, SD = 2.63), t(84) = -1.08, p = .28]. The results show that women did not demonstrate a greater degree of socially desirable responding than men did. Neither form of socially desirable responding was found for either men or women (all ps > .24).

![Graph showing self-reported attraction to friend](image)

**Figure 1.** Error bar graph displays of men's and women's self-reported attraction to their friend (first panel), and a comparison of those self-reports with men's and women's estimates of their friend's attraction to them (second and third panels).

**Relationship Status.** The first panel of Figure 2 displays sexual attraction to a friend as a function of participant gender and their own relationship status. Thirty-three percent (N = 29) of the men in the sample claimed current involvement in an exclusive dating relationship. These men reported a similar level of sexual attraction to their friend (M = 5.07, SD = 2.40) as men who were not currently in an exclusive dating relationship [(M = 4.89, SD = 2.56), t(85) = -.32, p = .75].

![Graph showing attraction to friend](image)

**Figure 2.** Error bar graph displays of men's and women's self-reported attraction to their friend as a function of participants' own relationship status (first panel) and as a function of participants' perception of their friend's relationship status (second panel).

Thirty-eight percent (N = 33) of the participants stated that they were currently involved in an exclusive dating relationship. Similar to the pattern for men, the reports of involved women showed a similar level of sexual attraction to their friend (M = 3.73, SD = 2.10) as those of women not currently in an exclusive dating relationship [(M = 4.11, SD = 2.18), t(85) = .81, p = .42].

The second panel of Figure 2 displays sexual attraction to a friend as a function of participant gender and perception of friend's relationship status. A total of 29 men reported that their friend was involved in an exclusive dating relationship with someone. In six cases, men said that their friend was not involved in a relationship although that friend reported that she was. In two cases, men said their friend was involved in a relationship but she said that she was not. Men who thought that their friend was romantically involved with someone reported a similar level of attraction to their friend (M = 5.24, SD = 2.30) as those men who thought their friend was not currently involved.
in an exclusive dating relationship \((M = 4.80, SD = 2.59), t(85) = -0.77, p = .44\).

A total of 23 women reported that their friend was involved in an exclusive dating relationship with someone. In six cases, women said that their friend was not involved in a relationship, although that friend reported that he was. In two cases, women said that their friend was involved in a relationship when he said that he was not. Women who thought that their friend was romantically involved with someone tended to report less attraction to their friend \((M = 3.30, SD = 1.71)\) than those women who thought their friend was not currently involved with someone \((M = 4.20, SD = 2.24), t(50.81) = 1.98, p = .05\).

**Duration of Friendship.** To investigate whether sexual attraction in opposite-sex friendships is stronger initially and then wanes, we conducted bivariate correlational analyses of the links between friendship duration and sexual attraction. For neither men \(r(87) = .01, p = .93\) nor women \(r(87) = .05, p = .68\) did sexual attraction to their friend prove stronger among friendships of greater or lesser duration.

**Desire to Date Friend**

**Sex and Sociosexual Orientation.** As shown in Table 1, men tended to have a stronger desire to date their friend than did women \((p = .08)\). More sexually unrestricted men tended to report a stronger desire to date their friend \(r(85) = .18, p = .10\), whereas sociosexual orientation was not linked to women's desire to date their friend \(r(87) = -.05, p = .67\). Again, the marginally significant difference in desire to date one's friend was not a product of men's greater sexual unrestrictedness, because men's greater desire to date compared with women's did not vary in magnitude at varying levels of sociosexual orientation \(\text{repeated measures interaction } F(1, 84) = .94, p = .34\).

The first panel of Figure 3 shows men's and women's self-reported desire to romantically date their friends, and the next two panels of Figure 3 display a comparison of those self-reports with men's and women's estimates of their friends' desire to date them. The second panel of Figure 3 displays findings similar to the pattern for sexual attraction; men overestimated their friend's desire to date them \(\text{men's estimate vs. women's self-report, } t(85) = 3.47, p < .01, d = .37\). The third panel displays women's reasonably accurate estimate of their friends' desire to date them \(\text{women's estimate vs. men's self-report, } t(85) = 1.09, p = .28\).

![Figure 3](Image)

**Figure 3.** Error bar graph displays men's and women's self-reported desire to date their friend (first panel), and a comparison of those self-reports with men's and women's estimates of their friend's desire to date them (second and third panels).

**Socially Desirable Responding.** To test for the possibility that women report lower levels of attraction to their friends because of unconscious self-deception or conscious engagement in impression management, we conducted associations, within each gender, between socially desirable responding and desire to date one's friend. Paralleling the pattern of findings for attraction to one's
friend, data analysis here showed that neither men nor women associated socially desirable responding with reported desire to date one's friend (all ps > .17).

Relationship Status. The first panel of Figure 4 displays desire to date one's friend as a function of participant gender and participant's own relationship status. Men who were currently involved in exclusive dating relationships reported similar levels of desire to date their friends (M = 4.72, SD = 2.07) as those men who were not currently in exclusive dating relationships [(M = 4.46, SD = 2.59), t(68.54) = -.52, p = .75]. Women who were currently involved in an exclusive dating relationship reported less desire to date their friends (M = 3.12, SD = 2.15) than those who were not currently in exclusive dating relationships [(M = 4.31, SD = 2.68), t(85) = 2.17, p < .05].

![Figure 4](image)

Figure 4. Error bar graph displays of men's and women's self-reported desire to date their friend as a function of participants' own relationship status (first panel) and as a function of participants' perception of their friend's relationship status (second panel).

The second panel of Figure 4 displays desire to date one's friend as a function of participant gender and perception of friend's relationship status. Men who thought that their friend was romantically involved with someone reported a similar level of desire to date their friend (M = 4.86, SD = 1.98) as those men who thought their friend was not currently involved in an exclusive dating relationship [(M = 4.39, SD = 2.61), t(71.54) = -.94, p = .35]. Women who thought that their friend was romantically involved with someone reported less desire to date their friend (M = 2.78, SD = 1.91) than did those women who thought their friend was currently unattached [(M = 4.25, SD = 2.65), t(54.05) = 2.84, p < .01].

Friendship Duration. We conducted bivariate correlational analyses of the links between friendship duration and desire to date one's friend. For neither men [r(86) = .02, p = .84] nor women [r(87) = .00, p = .98] did desire to date one's friend prove stronger among friendships of greater or lesser duration.

Sexual Events Between Friends

Table 2 shows the number (and percent) of male and female friends who reported telling their friend about their attraction to them, and the number who reported that they and their friend had romantically kissed, fooled around, or engaged in sexual intercourse. Averaging across the two genders' reports, approximately 25 percent had discussed attraction, 25 percent of friendship pairs had kissed, 11 percent had "fooled around," and 3 percent had engaged in sexual intercourse. Because each member of the friendship pairs reported separately on sexual events, some discrepancy arose between friends on those reports. However, in each category a majority of friends agreed. For example, 17 men said they and their friend had romantically kissed, and 16 of their female friends said the same. Interestingly, 26 women said they and their friend had romantically kissed, yet only 16 (62%) of these women's male friends said the same. Perhaps the young men and women in this sample had different views of what "counted" as romantic kissing.

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Table 2. Sexual Events Between Opposite-Sex Friends.

<table>
<thead>
<tr>
<th></th>
<th>Number (%) of men who said they...</th>
<th>Number (%) of men's friends who agreed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Told friend of attraction to her</td>
<td>24 (28%)</td>
<td>20 (83%)</td>
</tr>
<tr>
<td>Romantically kissed</td>
<td>17 (20%)</td>
<td>16 (94%)</td>
</tr>
<tr>
<td>Fooled around</td>
<td>11 (13%)</td>
<td>7 (64%)</td>
</tr>
<tr>
<td>Had sex</td>
<td>3 (4%)</td>
<td>2 (67%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Number (%) of women who said they...</th>
<th>Number (%) of women's friends who agreed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Told friend of attraction to him</td>
<td>18 (21%)</td>
<td>14 (78%)</td>
</tr>
<tr>
<td>Romantically kissed</td>
<td>26 (30%)</td>
<td>16 (62%)</td>
</tr>
<tr>
<td>Fooled around</td>
<td>9 (10%)</td>
<td>7 (78%)</td>
</tr>
<tr>
<td>Had sex</td>
<td>2 (2%)</td>
<td>2 (100%)</td>
</tr>
</tbody>
</table>

To track when romantic and sexual events occurred in these friendships, we created a series of scatter plots (see Figure 5) that displayed the duration (in weeks) of the participants’ friendship at the occurrence of a given event, as a function of the total duration of their friendship. As displayed in Figure 5’s panels, many, but not all, sexual events occurred within the first 100 weeks (2 years) of friendship.

Male and female friends’ reports agreed on whether alcohol was involved when a given act occurred. Of the 17 men who reported romantically kissing their friend, 8 said that both they and their friend were intoxicated at the time. Of the 26 women who reported romantically kissing their friend, 17 said that they themselves were intoxicated and 16 said their friend was intoxicated. Of the 11 men who reported fooling around with their friend, 5 said they were both intoxicated; and 5 of the 9 women who reported fooling around with their friend said they were both intoxicated. Finally, 2 of the three men who reported having sex with their friend said they were both intoxicated, and both of the women who reported having sex said both members were intoxicated.

Discussion

Sexual Attraction in Friendship

In this study we provide further evidence that, at least in young adulthood, men experience more sexual attraction to their cross-sex friends than do women. We documented this sex difference in the first systematic investigation to request reports from both members of each friendship pair. Men’s greater sexual attraction was not explained by their greater sexual unrestrictedness; neither was it explained by socially desirable responding on behalf of either sex, nor by the “type” of friend in mind when asked to discuss a cross-sex friend, nor by friendship duration. Thus, the finding appears to be robust. One possibility we cannot test with the existing data is that the young women in this sample were objectively more attractive than were the men. On one hand, it is possible that men who engage in the emotional support and companionship of cross-sex friendship may indeed tend to be more investing and less “sexy.” On the other hand, if women engage in cross-sex friendships for mate value affirmation (Bleske & Buss, 2000), or if women who engage in casual sex or extra-pair sex frequently do so with a cross-sex friend, then women have as much to gain as do men from engaging in friendships with attractive members of the other sex. Future research could collect self-reports and objective judges’ ratings of friends’ attractiveness, as well as data on the frequency with which individuals’ extra-pair sex partners are cross-sex friends.
Figure 5. Scatter plot displays of friendship duration (in weeks) when a sexual event occurred in the friendship. Male perspectives are displayed on the left, and female perspectives on the right.
The issue of cross-sex friendship and extra-pair sex may be especially important in thinking about middle adulthood, when a majority of individuals are working to maintain lasting partnerships. In the current sample of young adults, only women associated their own current involvement in a romantic relationship with less romantic interest in a friend. And, only women associated their friend’s current involvement with less romantic interest in that friend. Men’s romantic interest in their friend did not consistently vary as a function of their own or their friend’s relationship status. These findings support those of Bleske-Rechek and Buss (2001), who found that, in both a college sample and a community sample of young adults, men were similarly motivated by sexual desire in their friendships regardless of their current relationship status. Research focused directly on middle-aged adults in the larger community is strongly needed. Do middle-aged men in committed partnerships feel levels of sexual attraction to their cross-sex friends similar to those of men not so involved? If so, what are the implications? Perhaps one’s satisfaction with and commitment to one’s current relationship, rather than mere involvement in a relationship, function as better predictors of one’s level of sexual attraction to cross-sex friends. In any case, accepting that sexual attraction exists between men and women in the friendship context might help further research devoted to understanding the circumstances in which cross-sex friendships facilitate long-term relationship satisfaction, the circumstances in which cross-sex friendships endanger long-term relationship satisfaction, and the circumstances in which they serve as an indicator of long-term relationship dissatisfaction.

**Sexual Events Between Friends**

Similar to the findings documented by Afifi and Faulkner (2000), our data showed that alcohol was involved in the majority of sexual events that had occurred between friends. If alcohol expedites in some cases the release of one’s inhibitions, this finding suggests that cross-sex friends may let down their defenses around one another when alcohol is in the picture. A more important finding is that, among these men and women who are still friends, a substantial minority had either spoken of attraction to the other, or kissed or “fooled around.” Afifi and Faulkner (2000) reported that many individuals in their sample felt that sexual acts in their friendships had enhanced the relational quality of their friendship (and for many it led to the initiation of a romantic relationship), but their participants were reporting on past friendships in general. Given our sample of friendship pairs who have “lived to tell,” it is unclear how frequently a sex act led friends to discuss the status of their relationship, to transition into a romantic relationship, or to dissolve the friendship. Our findings, then, beg more detailed, longitudinal data on the circumstances leading up to sexual acts between friends, and the friendship dynamics afterward.

**Conclusion**

The current study adds to research that documents that men and women experience sexual attraction and romantic interest in their friendships. Our findings demonstrate, first, that men experience greater sexual attraction to their friends than do women – regardless of whether they or their friend is involved, whether they are interested in short-term or long-term partnerships, or how long they have been friends. Women’s romantic interest in their friends, however, hinges more than does men’s on their own or their friend’s romantic involvement with another. Second, our findings demonstrate that men overestimate how sexually attracted their female friends are to them, whereas women underestimate how attracted their male friends are to them. Although various researchers have emphasized that men and women can, indeed, be “just friends” (Monsour, 2002; Werking, 1997; Reeder, 2000), and we concur, we also suggest that sexual attraction between cross-sex friends is no surprise when these friendships are viewed through an evolutionary lens. A thorough understanding of how cross-sex friends interact and the benefits they provide each other throughout the
life span will necessarily include an analysis of how cross-sex friendships are integrated into—and impacted by—men’s and women’s mating strategies.

References
Hoggard, L. (2006, January 8). Just good friends...honest! *The Independent,* accessed online at: http://news.independent.co.uk/media/article 337174.cce
Causes and Features of Migration
"Einwanderungsland"

Although Germany has emphasized in recent years that it is not an Einwanderungsland (an immigration country), this claim falls apart when one views the nation's immigration history. It is not a new phenomenon for German companies to employ foreigners; as early as 1895, nearly 315,000 foreigners worked in the Deutsches Reich, the majority of them from Poland. In 1900 the figure grew to 500,000 and peaked in 1907 with 950,000 foreign workers (Voelker 332). One cannot ignore the massive labor migration, much of it forced, that occurred during the rule of the Nazis. Approximately eight million laborers from all over Europe, including two million interned in prisons and concentration camps, worked in Germany to support the Third Reich's war effort (Kurthen 917). After World War II, very few of these laborers stayed in Germany, whereas the majority chose to travel overseas.

The destruction caused by the war created a need for manual labor to rebuild the devastated cities, a need that ultimately could not be satisfied by the native population. Unemployment was virtually eliminated by the huge economic growth that occurred in Germany following the war, and initially the hefty labor demand was met by workers from Eastern Germany. In 1961, however, the wall erected between East and West Germany effectively cut off a large supply of labor for West Germany. This forced the nation to turn to other countries to recruit foreign manpower. In 1960, before the separation of East and West Germany, the total foreign work force in the country numbered 200,000. By 1966, this figure rapidly exploded to an astonishing 1.3 million foreign workers (Voelker 332).

The Federal Republic of Germany used a rotation system to employ foreigners, in which the workers were to stay for one to three years, then return to their homelands. The first such labor recruitment agreement was signed with Italy in 1955—before the erection of the wall created the massive demand for foreign labor. Later agreements were signed with Portugal, Spain, Greece, Turkey, Yugoslavia, Morocco and Tunisia. Italians made up much of the foreign labor force until 1969, when Yugoslavia took the lead. By the beginning of 1972, however, the largest number of foreign workers in the Federal Republic of Germany came from Turkey, numbering approximately 511,600 (Voelker 333). This study will focus primarily on these latter, yet it is important to place them within the larger context of the immigration history of the country.

Economic Considerations

A careful consideration of the push/pull factors that lead to immigration proves an important aspect of any migration study. In the case of Turkish immigration to Germany, expansive economic growth and the closing of the East German boundary served as pull factors. In addition, a declining birth rate in West Germany, as well as steady upward mobility of indigenous workers
encouraged the recruitment of foreign labor. Nermin Abadan-Unat explained this phenomenon in further detail: "Cheap labor fed economic growth [in Germany] by holding down wages and maintaining high rates of profit, investment and expansion...migrants have been taking up strenuous, unpleasant, mostly unqualified jobs...thus permitting the labour force of the recipient country to move up into skilled or semi-skilled jobs" (1). On the other end, the push factors from Turkey included unemployment, poverty and economic underdevelopment. The Turkish government encouraged the migration of its citizens as a way to free themselves from the burden of a large number of unemployed workers, and to reap the benefits of remittances sent home by the workers to the families left in Turkey.

Features of Migration

The situation for the peasant farmer in Turkey prior to the massive migration movement was bleak. Mubecel B. Kiray argued that the main reason for migration to Germany was the change in pre-modern agriculture (212). With the advent of modern technology, the small farmers in rural Turkey had much less opportunity to sharecrop. These farmers went into debt, lost what small amount of land they had owned, and watched helplessly as large land-owners took over the countryside. The displaced peasants were forced to deal with the reality of starting a new form of life in a non-agricultural sector, in other words, migrating from the countryside to an industrial area. The disenfranchised farmers did not, however, go directly to Stuttgart and Berlin. They went first to large cities within Turkey, such as Istanbul or Ankara. These urban environments simply could not provide enough employment for the massive influx of potential workers, who found themselves forced to look to countries with a labor demand, countries such as West Germany.

On October 30th, 1961, West Germany and Turkey signed the first bilateral agreement promoting employment of Turkish workers in Germany. There were initially no limits to the number of workers Germany would admit, as the goal was to "bring large numbers with little fuss" (Bendix 28). The recruitment process was straightforward: first, an employer filed a request for foreign labor; Turkish workers then needed to provide an application, a form of identification, and proof of marital status to the employment agency in Turkey. Next, applicants took a medical examination to determine if they were fit for work. Thereafter, the employer offered the workers still in Turkey a one-year bilingual working contract to sign. After signing, workers received German ID cards and information about the place of work. Then the workers were transported to Germany. Eberhard De Haan commented on this process: "This procedure, as depicted, commits a foreigner toward [sic.] an unknown employer in a totally strange working place, with unknown working conditions. As the contract ends within one year, the future remains dark" (351).

These one-year contracts were re-issued at the discretion of the Employment Agency in Germany. Most were automatically renewed, unless one of the two countries cancelled the contract. Foreign workers also required a residency permit to work in Germany, but a different, special security agency oversaw the distribution of these permits. As De Haan lamented, "the dualistic structure of these agencies potentially jeopardizes the social existence of the foreign worker. It creates a typical atmosphere of unsecurity [sic.], fear and anxiety, as well as the feeling of temporary living, a strain under which most of the families are suffering" (351).

As previously mentioned, Turkish workers took on the most undesirable jobs in their new working environment, as Abadan-Unat described: "Due to their extreme mobility, resulting in major changes in social stratification, almost all dirty, physically exhausting, dusty, noisy, low prestige, repetitive jobs in highly industrial countries are relegated to foreign workers." She cited "entire production lines solely operated by Turks" and teams of Turkish workers erecting an entire block of buildings. Somewhat ironically she named the three requirements necessary for the labor done by foreign workers: physical endurance, sharp eyesight and a quick grasp (21-22). Turkish workers
Erin N. House

comprised 25% of the automobile industry workforce, 35% of the mining workforce, 22% of the restaurant and hotel workforce, and 19.5% of the textiles workforce in Germany in 1982 (Mushaben 131).

Features of Migrants

In the initial stages of migration, men constituted the majority of the Turkish workers in Germany, but the ratio of women workers grew from 8% of all Turkish workers in 1967 to 24.4% in 1973 (Abadan-Unat 9). The migrating Turkish workforce was also very young. The age distribution in 1972 was 9% under 25, 21% ages 25-30, 33% ages 33-35, 22% ages 35-40, and only 10% over age 40 (Abadan-Unat 10). Most Turkish immigrants were unskilled laborers, but some downward mobility within this population has been noted: “Downward mobility is most strikingly represented by a shift from white collar to blue collar jobs, such as in the case of teachers and civil servants taking up industrial employment. The fact that as many as 9,000 former primary school teachers are mostly engaged in industrial jobs, indicates the strong attraction of high wages” (Abadan-Unat 12).

When the Turkish migrants first embarked on their expedition to Germany, most knew nothing about what awaited them, having received little to no briefing about what to expect from their new homes. Largely passive as they prepared to leave Turkey, most concerned themselves with the daunting logistical elements of their impending journey. Most had never been outside the country, spoken a foreign language, encountered a different culture, or faced negative receptions to their presence. Unprepared for the social challenges that awaited them, many “for reasons of job opportunities, feelings of belongingness, [and] expectations of assistance from their fellow countrymen” tended to concentrate in certain neighborhoods within a city (Abadan-Unat 8). Sticking to themselves, Turkish immigrants emphasized their foreignness, resulting in little mixing or communication with Germans. This accelerated formation of ghettos and marginality from the mainstream host society. Turkish migrants also faced adjustment difficulties in their places of work. As many of these workers came from farming villages, the new industrial work environment proved strange and disconcerting. The German climate is harsh in comparison to Turkey’s, the German language is difficult, and German rules and regulations at work seemed strict and confusing. All of these aspects made the transition to a new job even more challenging for the Turkish worker.

Status within the larger host society further complicated the experience of the Turkish migrant worker in Germany. James E. Akre addressed this issue in his paper, “Turkish Administrative Structures and the Migrant Worker.”

Although official policy in the Federal Republic of Germany still clings to the notion that foreign workers are present in the economy on a “temporary” basis, it has become increasingly clear in recent years that many of these workers have adopted quite different intentions. The inclination to remain for longer periods and eventually settle abroad, not surprisingly, has replaced the intentions of many workers who had initially anticipated staying only a few years. (197)

As previously mentioned, the first Turkish workers were accepted to Germany based on a rotation model, according to which workers stayed for one to three years, then returned to their country of origin. Once it became apparent, however, that many immigrants had no intention of returning to Turkey, German policy makers were forced to consider an integration model. Confusion arose, however, because the public, the workers, and the politicians held no clear policy about the immigration. Hermann Kurthen wrote, “The government nurtured for decades the perception that labor migrants were temporary guestworkers who could be sent home when jobs got scarce in Germany. Among many Germans this upheld the self-deceptive notion that the country is and will not become an immigration country” (923-924). This ambiguous status caused much uncertainty.
for Turkish migrants, even more so for those who were still uncertain about returning to their home country. A 1971 survey showed that 5% of Turks wanted to stay less long than intended, 27% decided to stay as long as they intended, 31% wanted to stay longer and a full 37% had no opinion (De Haan 353). Abadan-Unat emphasized the effects of the Turks’ confused understanding of their place in German society when she wrote, “The feeling of ‘temporariness’ due to the ambivalent attitude towards return to the home country or prolongation of their stay abroad, imbues all future plans and affects their motivation toward language learning, selection of residential place and investment in their savings” (3).

Effects of Migration
Effects on Germany

In general the economic impacts of Turkish immigration to Germany were initially positive. The demand for labor was met, which led to an increase in production, resulting in a higher gross national product (GNP). Another constructive aspect of the influx of immigrants for the Germans was a redistribution of income. As foreign workers took on unskilled work, the native population moved into more skilled, better paying occupations. This fact led Gottfried Voelker to comment, “It may be possible that a decline in the average per capita income, based on the total living population in Germany, may actually hide an increase in per capita income for the Germans but a decrease for the foreigners” (337). Günter Schiller also discussed this income differentiation in his paper “Mutual Perspectives of Development and Underdevelopment in Europe.” He lamented how the foreign workers provided the productive basis on which the economy depended, yet were taken advantage of by the higher social classes:

The income differentiation forms in itself a system of exploitation. Certainly high level income groups live at the expense of low paid groups. But even within the workers’ stratum which may on the whole be on the loser’s side this system of discrimination and privileges also works: men against women, the semi-skilled against the unskilled. In the Federal Republic of Germany we find a range of 40-50 wage groups among workers only, not to speak of clerks, professionals, entrepreneurs or politicians. And the fact that it stretches very far into the lower social strata (hence the fight for its persistence takes place on all levels of the social hierarchy) gives an amazing stability to the hierarchy of income. It is in this context that the phenomenon of migration must be understood, and it becomes immediately clear how functional migration has been for the maintenance of the social processes. (373)

Despite this important function of migrant workers, however, the German government issued an action program in June of 1973 to consider consolidating the foreign workforce. In the autumn, when the worldwide oil crisis and economic recession set in, the government decided to halt all foreign recruitment (Arbeitsstop), intending to reduce the immigrant population in Germany. While this action stabilized numbers for a time, Arbeitsstop’s desired goal was ultimately unrealized, as will be later discussed.

Effects on Turkey

The hiring freeze of 1973 had devastating effects on the Turkish economy. Since the inception of the guest worker agreement in 1961, Turkey had enjoyed an average economic growth rate of 7% each year, in part due to the guest worker programs. The Turkish workers sent home remittances from their higher paying jobs in Germany, thus preventing the state from having to borrow as much from other countries. Guest workers not only also gained valuable industrial skills that they could bring back to Turkey, but their massive migration from the Turkish countryside
reduced unemployment and allowed wages to remain relatively stable in Turkey.

Once Germany instituted the Arbeitstag, however, fewer remittances reached Turkish soil. It became more difficult for Turkey to export goods and its debt increased. In order to stabilize the Turkish economy, the 1978 International Monetary Fund was instituted. The program's four parts included a reduction in local wage rates, a reduction in tariff barriers and removal of subsidies (leading to an increased cost of living), a shift in export orientation from paying debts to the West to opening markets in the Middle East, and sending Turkish workers abroad to work in Turkish companies in the Middle East and North Africa (Furniss 73). With these measures, the importance of foreign workers in Europe dropped.

Effects of Migration on the Family Left in Turkey

The fragmentation of Turkish families caused by one or both parents seeking employment in a foreign country was a serious issue. Mümbeccal B. Kiray's "The Family of the Immigrant Worker" emphasized this significance:

In 1964 when Abadan first studied the Turkish workers in Germany their number had already reached 27,501. Among these workers 55.7 percent were married (57.4 percent of the men and 44.8 percent of the women). In 1973 the number had risen to 650,000 and the ratio of married [workers] had risen to 78.4 per cent. As the process is still continuing, the family of the immigrant worker has become, indeed, very relevant. (212)

A common impetus for migration was to provide for a family, yet the long periods of spousal and parent/child separation made many speculate if the higher income was worth such a price. Surveys over the years had shown that 70-76% of Turkish workers left their families behind, allowing for only brief vacation reunions. Children were often born while the father was away. Some immediate consequences of this fragmentation were "alienation within marital life, mistrust among spouses, fear of divorce, neglect of children, and deprivation of affection" (Kagitcibasi 115). Families also enjoyed some positive effects, such as increased mobility, changes in consumption leading to an increase in material belongings, and better clothes and housing. Family members were also allowed to become more independent, as the family structure itself changed.

Turkish families, typically nuclear in structure with a mother, father and any unmarried children residing together, interact in important ways with the extended family once a parent (typically the father) pursued employment abroad. This nuclear structure was disrupted. As Kiray wrote, "For the migrant family the discriminatory characteristic is the ultimate dispersal of the members of the nuclear family and the continuous change of its composition from one time to another as long as the men remain abroad" (216).

The fractured family of the migrant worker adopted one of several possible living arrangements. Both the husband and wife could live abroad, leaving the children with relatives in Turkey, or the women and children moved in with parents or in-laws. Oftentimes the wife became the head of the household. The main base of the family was where the woman lived; this location was defined as "home," and no matter what shape the new family took, the woman assumed the task of trying to hold the nuclear family together, making her the crucial person from whom sacrifices are asked to be made to provide the best possible composition of the family to meet the needs of the situation" (Kiray 220). For such newly autonomous women, the requirement to manage money, visit banks, post offices and agencies, manage land (what little was left), and serve as principal authority over the children greatly influenced the importance of the wife's role. Kiray described the stress put on women who took over the positions their husbands had once held in the family structure:

She herself seems to be going through great strains of change, pressure and de-
privation; but in spite of all such overwhelming obstacles the women take the
most important steps from a dependent subservient role in the family, *vis-à-vis*
her husband and her husband’s extended family kin, and becomes an independ-
ent member of the nuclear family where she acts as the coordinator and deci-
dision-maker on almost every aspect of the affairs concerning her nuclear family.
(221)

Children left in Turkey also faced unique challenges. Lacking a male head of the house-
hold, children, especially boys, assumed greater participation than accustomed. The strongest rel-
ationship in traditional Turkish families lay between father and son, where the boy would learn
the family trade, be found a suitable wife, and have the future family welfare entrusted to him. As
a result, spoiled and favored male children held, often by the age of ten, a higher status within the
family than the mother. With the migration of the father abroad, however, this structure broke
down. The mother became stricter with the boys, demanding that they share in the familial re-
sponsibilities. Kagitcibasi cited a further effect of migration on children left behind in Turkey:
“psychological disturbances and even psychiatric symptoms have been reported among children left
behind, the prolongation of father absence again being cited as an aggravating condition” (117).
The mothers’ authority and discipline, contrasted to that in traditional families, no doubt led to
children’s confusion. Experiences such as trips abroad, anxieties caused by parental absence, and
the overall changing form of family life marked this development.

Effects on Migration on the Reunited Family

When Germans stopped recruiting foreign workers in 1973, they hoped to reduce the
number of Turks in Germany; however, immigration due to family reunions increased after this
time. Many of the workers already in Germany decided to stay in the country longer than they had
initially anticipated. As John Bendix reported, “due to changes in various regulations, [the Arbeits-
to] froze the total number of workers, while still allowing family members of workers to enter, with
the result that the absolute numbers of foreigners continued to grow” (29). Immigration based on
family reunions became the largest category of immigration to Germany after 1974, accounting for
90% of all immigrants (Kurthen 923). These Turkish families maintained high birthrates, causing
the overall foreign population to grow while the number of workers remained constant.

The immigrant family faced its own set of challenges when attempting to adjust to life in
the new country. As Kagitcibasi noted, “cultural assimilation has not been an aim of the migrant,
or the sending country or the initial immigration policy of most receiving countries” (117). Due
to this lack of integration, the Turks, often resisting assimilation, experienced marginalization and
treatment as inferiors. In recent years, as the duration of the stay increased, family reunions have
become commonplace. In addition, as intermarriages with native Germans have occurred, and
more workers have expressed the desire to permanently stay in Germany, public opinion has shifted
to try to incorporate foreigners. Nonetheless, much ambiguity, resentment and controversy re-
mains.

Within Germany, the immigrant family struggled with structural instability. Time, space,
and monetary requirements changed and required family members’ adaptation and planning.
Strong ties to the home country made it difficult for Turkish families to feel at home in their new
environment, and—similar to the situation of families left in Turkey—changing gender roles within
the family created additional difficulties.

Working women received more autonomy in Germany, yet they encountered consider-
able pressure from having to labor both inside and outside the home, and deal with the children’s
demands. They faced the moral values of their peers as a kind of social control: traditional opinion
how proper Turkish women should behave—a code that often contradicted the freedom German
society allowed them. All of this, coupled with challenges of discrimination, transition from rural to urban life in a foreign country, and language barriers presented insurmountable obstacles for these women, obstacles that Kagitzbasi wrote “may even result in psychological disturbances such as psychosomatic diseases, depressive reactions, anxiety, sexual problems, etc, all labeled ‘guest worker syndrome’” (118).

Problems Presented by Immigration

German National Identity

Germany’s resistance to declaring itself an immigration country begs the question why. Why is this nation so hesitant to embrace a foreign population as its own? Hermann Kurthen postulated that lingering nationalistic sentiments of the past still remain potent in the collective German identity. From the belated 1871 unification under Bismarck, to the nationalistic fervor preceding World War I, to the isolation and devastation Germany faced after the war, attempts to unite ethnic Germans have remained a major and persistent theme of the none-too-distant past. The racist policies of the Nazis, “built on the fertile ground of the political and economic instability of the Weimar Republic, of nationalistic humiliation and corresponding ethnocentric and racist hubris” cannot be ignored as shapers of German national identity, especially in light of the indirect effects they wrought to unify German citizens following the wreckage of World War II:

Ironically, after unconditional surrender, expulsion of millions of German ethnics from former Eastern territories, and years of occupation regime, a partitioned country evolved under the supervision of the victorious allies that represented a nation ‘ethnoculturally homogenous’ to an extent even the Nazis had not dreamed about, though considerably decimated in number, size and power status. The rebuilding of the divided country from the rubble helped to rebuild national pride, solidarity, and identity—this time bolstered by confidence in superior economic, monetary, and technological abilities that would peacefully conquer markets and win the confidence of consumers around the world. (Kurthen 918)

These historical realities provide important considerations in any understanding of the complicated relationship Germany maintains with its migrants and the laws regarding citizenship.

The Question of Citizenship

For years, German citizenship rested solely on the principle of *jus sanguinis*—the ancestral, parental principle. In comparison to the principle of *jus solis*—the territorial principle—the only way to become a German citizen was to have at least one parent who already held citizenship. Being born on German soil was not enough to grant the right of citizenship. This strict principle, according to Kurthen, dates back to the nineteenth-century ideal of nation, or *Volk*, which stressed “common language, history, ancestry, moral principles, social values, and other commonalities” (929). The rebuilding efforts and isolation experienced by Germany through the Allied occupation immediately following World War II strengthened this policy. In addition, West Germany immediately granted citizenship rights to East Germans who fled the Stalinist regime, and provided a safe environment for other ethnic Germans who experienced forced expulsion following the war.

Foreigners in Germany, however, were viewed as belonging to another nation. Migrant workers, “offered integration without naturalization” under the Alien Law (Kurthen 930), were temporary residents for whom no need existed to consider citizenship. While allowed full legal equality and access to Germany’s generous social security system, they lacked political participation, voting rights, and access to tenured civil service jobs.

Not surprisingly, the level of naturalization remained markedly low in Germany. As of
1995, the ratio was about 3% of the seven million resident foreigners, compared with 6% in the U.S.A., 8% in the Netherlands, 8% in Australia, 4% in Sweden, 4% in Canada, 2.5% in the U.K. and 1.3% in France (Kurthen 932). To achieve German citizenship, an immigrant had to express the desire to remain in Germany, demonstrate a basic understanding of the political structure, have a command of German, live at least ten years in Germany, possess a secure job and no criminal record. The rationale for these requirements was that naturalization should only occur after successful integration.

Critics of this policy stressed that the nationality law was too strict and exclusionary. As early as 1985, John Bendix addressed this controversial issue and its ramifications: “Citizenship implies sharing in the heritage of German society, and this includes rights and duties, but how residents who are not citizens will share is unclear. Germans share Germany with foreigners, but it sometimes appears that they wish to do so without sharing rights or membership in the majority culture” (24).

In 2000 the German nationality law changed to include a provision that all children born on or before January 1, 2000 on German soil were granted German citizenship if at least one parent had lived in Germany for eight consecutive years and had held permanent residency for three consecutive years. Such children must apply for citizenship before their 23rd birthday, and must not hold citizenship of any other country.

Marginalization

There is no denying that Turks seem especially “foreign” to Germans. Their language, food, dress, and customs, as well as their upbringings and cultural background differ significantly from customary German norms. When Turkish migrants first arrived in Germany, they expected Germans to be open and friendly, as people in Turkey tended to be; the reaction they received, however, was as unsettling as it was unexpected. The hostile reception was documented by John Bendix in Tables 1 and 2. He reported an ugly mood in Germany regarding foreigners, with lower-class Germans feeling economically threatened. Xenophobia ran rampant, discriminatory signs adorned restaurants, and Neo-Nazi uprisings provided chilling images. A 1981 poll showed that 82% of German respondents believed there were too many Turks in Germany (Bendix 41).

<table>
<thead>
<tr>
<th>Pro statements</th>
<th>1964</th>
<th>1971</th>
<th>Con statements</th>
<th>1964</th>
<th>1971</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrifty</td>
<td>33</td>
<td>53</td>
<td>Loud</td>
<td>39</td>
<td>54</td>
</tr>
<tr>
<td>Industrious</td>
<td>22</td>
<td>43</td>
<td>Slovenly</td>
<td>30</td>
<td>41</td>
</tr>
<tr>
<td>Kind-hearted</td>
<td>17</td>
<td>30</td>
<td>After the girls</td>
<td>42</td>
<td>38</td>
</tr>
<tr>
<td>Helpful</td>
<td>15</td>
<td>27</td>
<td>Quick-tempered</td>
<td>27</td>
<td>37</td>
</tr>
<tr>
<td>Polite</td>
<td>16</td>
<td>25</td>
<td>Obtrusive</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>Handy, skillful</td>
<td>16</td>
<td>19</td>
<td>Untrustworthy</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Reliable</td>
<td>6</td>
<td>14</td>
<td>Lazy, work-shy</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Honest</td>
<td>6</td>
<td>14</td>
<td>Impudent</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Resourceful</td>
<td>8</td>
<td>9</td>
<td>Like to steal</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Too demanding</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

(Pro statements: 50, Con statements: 32, Source: Bendix, pgs. 42-43.)
### Table 2. Turkish, Italian, and Greek Attributes, according to Germans, by percentage, 1982.
(Source: Bendix, pgs. 42-43.)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Turkish</th>
<th>Italian</th>
<th>Greek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have large families</td>
<td>88</td>
<td>70</td>
<td>48</td>
</tr>
<tr>
<td>Exhibit very different behavior</td>
<td>69</td>
<td>47</td>
<td>42</td>
</tr>
<tr>
<td>Stay among themselves</td>
<td>64</td>
<td>39</td>
<td>44</td>
</tr>
<tr>
<td>Have a hard time here</td>
<td>61</td>
<td>45</td>
<td>47</td>
</tr>
<tr>
<td>Do work we don't want to do</td>
<td>60</td>
<td>54</td>
<td>41</td>
</tr>
<tr>
<td>Are simple people</td>
<td>59</td>
<td>42</td>
<td>40</td>
</tr>
<tr>
<td>Feel excluded</td>
<td>42</td>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>Are very frugal</td>
<td>40</td>
<td>23</td>
<td>28</td>
</tr>
<tr>
<td>Take away our jobs</td>
<td>39</td>
<td>32</td>
<td>21</td>
</tr>
<tr>
<td>Sometimes they scare you</td>
<td>31</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>Are industrious people</td>
<td>29</td>
<td>23</td>
<td>33</td>
</tr>
<tr>
<td>Don't care about cleanliness</td>
<td>26</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td>Are not as intelligent as us</td>
<td>20</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Take advantage of us</td>
<td>18</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Are often brutal, aggressive</td>
<td>17</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td>Are easily excited</td>
<td>16</td>
<td>36</td>
<td>10</td>
</tr>
<tr>
<td>Are friendly and polite</td>
<td>13</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>Are scared and unsure</td>
<td>13</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Are nice co-workers</td>
<td>12</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Have badly raised children</td>
<td>11</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Can cook well</td>
<td>9</td>
<td>37</td>
<td>34</td>
</tr>
<tr>
<td>Have no culture</td>
<td>8</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Are always happy</td>
<td>8</td>
<td>32</td>
<td>21</td>
</tr>
<tr>
<td>Are good neighbors</td>
<td>8</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Are just like us</td>
<td>6</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>One can learn much from them</td>
<td>3</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>None of the above</td>
<td>3</td>
<td>6</td>
<td>17</td>
</tr>
</tbody>
</table>

The terminology used to describe the immigrant population and its etymology are revealing. When the Turks first arrived in Germany, they were referred to as *Fremdarbeitern* (alien workers), a term which implies rejection. After a few years, the euphemism *Gastarbeiter* (guest workers) was adopted, emphasizing the temporary aspect of their presence. Once these "guests" took up permanent residency, the bureaucratic term *Ausländische Arbeiter* (foreign employees) came into use among some, but others argued that this term afforded immigrants more honor than they deserved. A German radio station once sponsored a survey to come up with an appropriate term for the Turkish workers. Out of 32,000 entries, suggestions included: *Ausländsbrüdern* (foreign brothers); *Hottoten* (slaves); *Menschen zweiter Klasse* (second-class humans); *Wirtschaftswunderbeschäftigen* (economic miracle accelerators); and *Ausländsröbotern* (foreign robots) (Bendix 29).
Despite continued harassment and graffitispattered walls proclaiming, “Türken raus!” (Turks out!), the Turkish immigrants still found themselves caught in a bind: leaving Germany’s racism would mean returning to the unemployment and economic hardships of Turkey. Most, therefore, chose to stay and withdraw into ghettos in order to afford themselves some measure of status and identity.

Abadan-Unat referred to the structural marginality experienced by Turks in Germany as a result of the unequal rights and opportunities as “undercasting.” Undercasting occurs when the lower stratum of a country’s native population is afforded upward mobility, while immigrants, due to their “foreigner” status, remain at the bottom. Antagonism occurred on both sides, between the perceived “in group” and “out group,” followed by Turks’ realization of the need for social and cultural identity (5). Because they were withdrawn from society, Turkish immigrants tended to be stereotyped and sensationalized in the media. All Turks were seen as the same, namely, NON-German. Journalists and the public did not strive to “cultivate contacts with foreign workers,” so an aura of mystery and mistrust surrounded this sizable population in the larger German society (Bendix 7). A vicious cycle formed: Germans rejected Turks; Turks withdrew into sociocultural isolation; Turks and Germans did not interact; negative stereotypes abounded about the isolated Turks; Turks remained marginalized from German society.

The problematic language barrier fed this predicament. Language, as a vital communication tool for adults, was a strong factor in the identity crisis experienced by Turkish immigrants. Their limited vocabulary made Turks’ misunderstanding of cultural messages and media comments common, and limited their ability to communicate with native Germans and even their own children! A 1980 survey showed that 29.5% of Turkish immigrants knew absolutely no German, and that only 13.5% attended language classes (Abadan-Unat 6). Several first-generation Turks were still torn about whether they wanted to return to Turkey; this made them hesitant to invest the time and effort required to learn German. What purpose would it serve, if they planned on returning home where they would never encounter that difficult language again?

Finally, as a result of their displacement and marginalization, many immigrants in Germany experienced a phenomenon that Abadan-Unat refers to as “Re-Turkization.” As previously mentioned, the Turkish migratory process involved two steps: from rural villages to large cities in Turkey, and then migration to Germany. Already in the first phase, the displaced Turks suffered from unemployment, rootlessness, status loss and meaninglessness, so they adopted rituals to compensate for these unsettling feelings—rituals of dress, prayer, and cultural prohibitions. In essence, as a reaction to the collapse of their identity as villagers, they adopted a subculture within the large Turkish cities. When they moved to Germany, this subculture took on an even more extreme form. As Abadan-Unat wrote:

Once these migrants achieve the second phase of displacement by migrating abroad, their social system is even more accentuated. Their only system of defense is to use their political identification and understanding of Islam to overcome the overwhelming rootlessness with which they are confronted. But it would be erroneous to interpret this as a return to the roots of Turkish culture; in reality this set of values and behavior code is the product of an urban subculture, so to speak, invented by the de-peasantized former inhabitants of Turkey’s squatter houses. (17)

After the migrants moved abroad, the threats they faced caused them to bond together and take extremely protective cultural measures. In this way, Turkish life in Germany often became more restrictive than in Turkey, especially for women, who tended to be cut off from German women and the larger society in general.
Education

The family fragmentation that characterized the early years of Turkish immigration to Germany was replaced by family reunions in Germany. The resulting birth rate increase led to a major policy problem in the 1970’s and 80’s, the issue of educating Turkish children. Schools debated whether to push for integration or to encourage biculturalism, although Mushaben critically characterized German educational policy as “improvisation rather than integration” (138). Indeed, a high drop-out rate existed among Turkish students, and it was reported that while students gained basic communication skills and linguistic fluency, they struggled to learn class material such as history, biology, and physics, due to their lack of academic language proficiency.

Because employment abroad was the main goal of families in Turkey, education was not heavily emphasized prior to migration. Once in Germany, however, parents wanted more education for their children than they had been afforded (See Table 3). As M. Sitka Bilmen reported:

It can be claimed that the problem of educating the children of migrant workers is nothing but a tiny fragment when compared to the huge mosaic of complicated problems created by the total migration question. But the fact is that what motivates millions of workers to toil like slaves in faraway countries is the idea of feeding the minds as well as the stomachs of their offspring, for most of them, from their personal experiences, realize fully that a well-fed brain will prevent the stomach from going hungry as theirs did. (238)

The problems regarding education of Turkish children in Germany involve parents, students, teachers, and German public policy. Turkish parents knew little about the German school system, such as how to enroll, school types and where to send their children. Often, they did not even know if they had long-term plans to stay in Germany, so were hesitant to send their children to school at all. If they did, parents often only sent the most talented boys to school, while less promising males were expected to work and girls were required to supervise younger children. Parents could not help children with their homework; their German was insufficient, and many simply did not have the level of education to be of much assistance.

<table>
<thead>
<tr>
<th>Level of Education Desired</th>
<th>For</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BOYS</td>
<td>GIRLS</td>
</tr>
<tr>
<td>Primary Education</td>
<td>5</td>
<td>94</td>
</tr>
<tr>
<td>Junior High School</td>
<td>17</td>
<td>154</td>
</tr>
<tr>
<td>S. High School and equivalent</td>
<td>105</td>
<td>21</td>
</tr>
<tr>
<td>Higher Education</td>
<td>343</td>
<td>194</td>
</tr>
<tr>
<td>School is not necessary</td>
<td>--</td>
<td>10</td>
</tr>
<tr>
<td>Response is not clear</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>494</td>
<td>494</td>
</tr>
</tbody>
</table>

As for the students themselves, not enough Turkish children attended pre-school or kindergarten to gain the benefits of early language development. In 1978, only 28% of Turkish children went to kindergarten, compared to 60% of German children (Mushaben 138). In addition, the “special classes”—instruction one year before regular classes—that were in place in some schools proved woefully ineffective, with a high failure rate among the students once they participated in regular classes. Turkish students received no special help or allowances once placed in regular classes.
classes; they were expected to adjust to a completely new school system after only a short period of time in the country. Another problem involved immigrant children's concentration in one or two schools, a circumstance that prevented their interaction with indigenous children and practice in the German language. Finally, the marginalization and discrimination Turkish children encountered at school caused them to feel socially ill at ease, which lowered their self-confidence and further inhibited learning.

In addition, most teachers in Germany lacked linguistic or professional training geared to the needs of immigrant children. No special workshops were instituted to offer teachers educational or methodological insights that may have proved useful. The inconsistent public policy on the part of the German government, which fluctuated between retaining Turkish culture and pushing for complete integration, further exacerbated the situation. Further complicating the matter were the different educational policies of different German Länder. For example, the school system in Bavaria gave parents free choice on whether to educate their children in Turkish or in German, while other, more industrial Länder pushed for full integration of Turkish children into German society, meaning they would enroll in brief transitional classes or join directly into regular classes in German schools.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>216,593</td>
<td>215,367</td>
<td>250,380</td>
<td>304,371</td>
<td>272,455</td>
<td>227,654</td>
</tr>
<tr>
<td>Greece</td>
<td>89,419</td>
<td>124,566</td>
<td>164,125</td>
<td>186,005</td>
<td>171,891</td>
<td>132,655</td>
</tr>
<tr>
<td>Spain</td>
<td>97,465</td>
<td>114,355</td>
<td>149,146</td>
<td>167,501</td>
<td>141,515</td>
<td>106,429</td>
</tr>
<tr>
<td>Portugal</td>
<td>1,857</td>
<td>2,584</td>
<td>6,893</td>
<td>15,231</td>
<td>19,035</td>
<td>16,745</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>36,442</td>
<td>42,904</td>
<td>48,827</td>
<td>68,673</td>
<td>90,474</td>
<td>84,805</td>
</tr>
<tr>
<td>Turkey</td>
<td>22,054</td>
<td>44,953</td>
<td>94,975</td>
<td>133,000</td>
<td>136,255</td>
<td>123,386</td>
</tr>
<tr>
<td>Total</td>
<td>668,969</td>
<td>764,230</td>
<td>952,461</td>
<td>1,126,593</td>
<td>1,068,025</td>
<td>903,591</td>
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</table>

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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>282,166</td>
<td>330,049</td>
<td>362,704</td>
<td>384,303</td>
<td>409,448</td>
</tr>
<tr>
<td>Greece</td>
<td>155,822</td>
<td>206,819</td>
<td>250,971</td>
<td>264,427</td>
<td>268,408</td>
</tr>
<tr>
<td>Spain</td>
<td>119,997</td>
<td>149,190</td>
<td>170,382</td>
<td>175,998</td>
<td>179,157</td>
</tr>
<tr>
<td>Portugal</td>
<td>22,107</td>
<td>32,802</td>
<td>47,387</td>
<td>57,180</td>
<td>68,994</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>148,439</td>
<td>296,970</td>
<td>415,461</td>
<td>434,893</td>
<td>465,611</td>
</tr>
<tr>
<td>Turkey</td>
<td>171,018</td>
<td>272,423</td>
<td>373,019</td>
<td>449,676</td>
<td>528,414</td>
</tr>
<tr>
<td>Total</td>
<td>1,136,899</td>
<td>1,575,072</td>
<td>1,964,213</td>
<td>2,158,680</td>
<td>2,346,800</td>
</tr>
</tbody>
</table>

**Table 4. Migrant Workers in Germany By Country of Origin (as of January).**
(Source: Abadan-Unat, pg. 387.)

**Special Challenges Facing the Second and Third Generations**

While first-generation Turkish immigrants faced their own fair share of problems when attempting to find their place in German society, their children and grandchildren faced even more daunting challenges. People from the first generation typically clung to a connection to home and found solace in collective identity, while the second generation may "opt for total assimilation, rejection through aggressiveness or withdrawal [and] apathy" (Abadan-Unat 5).

Children of Turkish immigrants are typically divided into two classes: integrated and un-
integrated children. Integrated children usually are born in Germany or migrate at an early enough age to gain a command of German, and are vital to the family and community for their translation abilities. Even at the young ages of 8-10, Turkish children translate letters, and interpret at stores and at police stations. Of the students who were born abroad or migrated to Germany at a young age, the most successful have attended preschool to gain extra exposure to the German language. They achieve good grades in school, yet suffer from the stress of a dual existence, hiding their real identity from both their family at home and their peers at school. A male Turkish student's perspective, reported by Abadan-Unat, described this experience:

Each day I travel from Turkey to Germany. When I leave in the morning the house of my parents, I actually quit Turkey. I then go to my work place or my friends and am then in Germany. In the evening, returning home, I am again in Turkey. At home I never tell anything that has happened at school, or with my friends, I just act in accordance with the expectations of my parents. When staying with my friends or at school I never mention my parents, there I am orienting myself according to the actions of my friends. (8)

The inconsistencies between home and school, such as different sex roles and sex-appropriate behavior, obedience, morals, discipline and independence, leads some Turkish youths in Germany to an identity crisis. Also, the agony of discrimination makes these challenges even more unbearable.

Those who are pulled to integrate into mainstream German society—often children who went abroad when they were older or girls kept at home to care for younger siblings—are quite alienated, lacking an adequate command of either Turkish or German. Making any attempt to enroll these “bilingual illiterates” in school proves very difficult; they no doubt had high hopes when first arriving in Germany, yet had no skills to deal with their new life. Abadan-Unat reported that when such youngsters face the reality of the crippling effects of their non-existent language skills and what it means for their future in Germany—namely, having to work in the same jobs their parents held—they become immensely frustrated and disheartened, with some becoming aggressive or running away (10).

The debate and controversy about the situation of Turkish immigrants continues today in Germany, with much of it focusing on the children and grandchildren of the original immigrants. Although the issues are complex, and almost daily becoming even more complicated, one thing remains clear: this sizable minority population is not going away. It is highly advisable, therefore, that the German government address the issues presented in this paper and others that may arise as soon as possible in order to prevent further marginalization and disillusionment within the Turkish community.

Works Consulted


Burnout Levels in Athletic Training Students Across a Semester

by

Stephanie J. López, Mary J. LaRue, and Dr. Jeffrey M. Janot, Department of Kinesiology

Objective: This study's purpose was to determine the level of burnout among athletic training students (ATSs) at various points throughout the Fall semester at an upper midwestern university.

Design and Setting: Two questionnaires were used for the purpose of this study: the Maslach Burnout Inventory (MBI) and a survey written by the authors to address questions that the MBI did not cover. Administrations of the questionnaires occurred during meeting or classroom situations. Each instrument took up to 15 minutes to complete and was given three times throughout the semester.

Subjects: The sample consisted of 62 ATSs enrolled in an undergraduate athletic training education program (ATEP) accredited by the Commission on Accreditation of Athletic Training Education (CAATE). Students came from one of two Division III midwestern universities selected for this study.

Measurements: The Maslach Burnout Inventory (MBI) and an additional questionnaire were used. Both instruments were given three times (start of semester, during season overlap, and before finals). Descriptive statistics were used to summarize survey data and MBI differences were analyzed using a two-way ANalysis Of VAriants between groups test (ANOVA), one by the school, the other by the administration.

Results: Overall, moderate levels of emotional exhaustion and low levels of depersonalization and high levels of personal accomplishment were reported. Significant differences were observed in emotional exhaustion scores on the MBI between the first two administrations. Significant differences in MBI depersonalization scores between administrations one and two and one and three were also observed. No significant difference in MBI subscale scores was found between schools.

Conclusions: Despite stress ATSs still enjoy what they do and feel they have sufficient support from athletic training staff and students. However, burnout still appears to be an issue for athletic training students. Levels of burnout increase during season overlap and at the end of the fall semester. ATEP staff need to be aware of these burnout levels and work to minimize them.

Burnout is a common phenomenon in the service professions because of the high interaction between the provider and the patient. Occurring when an individual becomes physically and mentally exhausted, burnout is accompanied by a sense of frustration, personal failure, and lack of concern for others. This condition is usually broken down into three components: emotional exhaustion, depersonalization, and personal accomplishment. Emotional exhaustion (EE) is characterized by feeling overworked, as well as being physically and emotionally exhausted. When experiencing depersonalization (DP), the individual becomes withdrawn and distances him/herself from coworkers and patients. He or she may also become unsympathetic and uncaring. Personal
accomplishment (PA) is a measure of feelings about one's achievements and oneself. A high level of burnout is marked by high scores on the EE and DP subscales; however, a low score on the PA subscale is also indicative of a high level of burnout. The unfortunate consequences of burnout include breaking down creativity, decreasing productivity, hindering job performance, and increasing the likelihood of mistakes. Furthermore, burnout results in exhaustion, pessimism, inefficiency, and an increased risk of illness. Working to help patients succeed proves more difficult when the caretaker is plagued by burnout.

Many factors appear to contribute to the levels of burnout among service professionals. Common factors influencing burnout among nurses, physical therapists, occupational therapists, and certified athletic trainers include lack of information, large workloads, conflict among co-workers, death/dying of patients, inadequate preparation, lack of support, patient compliance, medical complications, shortage of staff, insurance, chronic conditions, pressure from others, limited resources, poor working conditions, and salary. Several of these factors also apply to athletic training students (ATSs).

A study done by J. Balogun, Titiloye, A. Balogun, Oyeyemi, and Katz (2002) examined the incidence of burnout in physical therapists (PTs) and occupational therapists (OTs) in New York City. It was reported that the EE scores for the PTs and OTs in this study were lower than the normal scores reported by physical therapy students. In addition, the level of support from the PTs' or OTs' supervisor, number of children, and religious affiliation were predictors of EE. Several factors from past research that were expected to contribute to burnout were not found to be significant factors in this study. These factors included size of caseload, salary, lack of physical activity, patient population, years of experience, age, and gender.

While studying PT students, O'Meara, Kostas, Markland, & Preity (1994) found that many PT students were at a high risk for developing cardiac, neurological, respiratory, or psychological illnesses due to chronic stress. This may result in additional stress for the individual, perpetuating the cycle.

Certified Athletic Trainers (ATCs) also suffer from burnout. They have lower scores of PA than most other occupations. Campbell et al. (1985) reported that fatigue is most frequently cited as a result of burnout. Other symptoms often reported include irritability, problems with weight management, difficulty sleeping, high blood pressure, depression, upset stomach, and frequent headaches.

It is logical to think that if an ATC in an educational setting feels these stresses, his/her students may feel them as well. These students, under the supervision of an ATC, cover athletic events (practices, games, etc.) and help out in the athletic training room. Not only do students have to contribute significant amounts of time to these activities, but they also need to keep on top of the rigorous academic aspect of the athletic training education program (ATEP). In addition, ATCs may also experience frustration due to financial issues because the time spent doing athletic training related activities eliminates time for a normal part-time job. If the individual does have a part time job, he/she has even less time for studying and normal college life. Stilger et al. (2001) reported that during midterm examinations, ATCs may be more vulnerable to stress because of the increased academic pressure, as well as a large amount of athletic team related responsibilities happening at the same time. The responsibilities of an ATC may put him/her at a high risk for experiencing physical and psychological problems.

The purpose of this study was to determine the levels of burnout in ATSs across a semester at two Division III CAATE-accredited schools. We hypothesized that levels of burnout would be the highest during season overlap—when winter sports begin before fall sports end. Burnout is a complex issue to examine in any field. Hopefully this investigation will provide ATEPs a better understanding of what burnout is and how it changes throughout the semester. Such knowledge.
can allow ATEPs to better accommodate their students, resulting in lower levels of burnout and creating more effective ATCs.

**Methods**

**Subjects**

A total of 62 ATSSs from two Division III universities in the Midwest with CAATE-accredited undergraduate ATEP's participated in this study. Students ranged from second-year students (often sophomores) to fourth-year students (often seniors) in the programs. There were 20 males and 41 females (one person did not report gender). The average years in the program of the ATSSs was 2.9 (SD = 0.11) and the majority (32%) of participants were 21 years old. This study was approved by the University's Institutional Review Board. All participants provided informed consent.

**Instruments**

Two instruments were used for this study. The MBI, utilizing the three components of burnout (EE, DP, and PA), was used to determine the level of burnout among the ATSSs. The authors wrote an additional questionnaire in order to obtain further information from the ATSSs; this included demographics, rotation information, outside job hours, and concerns regarding participants' daily lives.

**Survey Administration**

ATSSs completed both questionnaires three times throughout the Fall semester. The first administration occurred during the fourth and fifth weeks of the semester, after students had settled into a pattern with their rotations and school. At least two of the three main researchers were present at the first administration to explain the study, obtain informed consent, administer the surveys, and answer any questions. The second administration transpired during the overlap of fall and winter sports during the ninth and tenth weeks of the semester (end of October and early November). The final administration took place during the fourteenth and fifteenth weeks of the semester.

**Statistical Analysis**

Measures of central tendency and variance were conducted for all variables in the questionnaire. For each burnout subscale (EE, DP, and PA), frequency tables were compiled for each level of burnout (high, moderate, and low). Two-way ANOVAs were calculated comparing schools and administration number for each burnout subscale (EE, DP, and PA). SPSS 14.0 (SPSS Inc., Chicago, IL) was used for all statistical analyses. The post-hoc test, Fisher's Least Significant Difference (LSD), was used to determine significant pairwise differences. Alpha level was set at .05 to determine statistical significance.

**Results**

No significant difference in MBI scores were found between schools. Therefore, for the purpose of the results, the school from which the student came was disregarded. Significant differences were observed in EE scores on the MBI between the first two administrations (p < .05). Significant differences in MBI DP scores between administrations one and two (p < .05) and one and three (p < .05) were also observed. A representation of the changes in MBI scores is available in Figures 1-3.

A low degree of burnout on the EE subscale is denoted by a score of zero to sixteen, a moderate level by a score of seventeen to 26, and a high level by a score of 27 or higher.

Mean values (standard deviations) of EE for administration 1, administration 2, admin-
istration 3, and overall were 16.19 (8.86), 20.95 (11.25), 20.36 (10.03), and 19.15 (10.27) respectively. The mean score for the first administration denotes a low level of burnout on the EE subscale. The mean scores of the second and third administrations and overall indicate a moderate amount of burnout on the EE subscale. A low level of burnout on the DP subscale is designated by a score of zero to six, a moderate level by a score from seven to twelve, and a high level by a score of thirteen and above. Mean DP scores were 3.02 (3.63), 5.16 (5.05), 5.08 (5.31) and 4.40 (4.79) respectively. These scores show a low level of burnout on the DP subscale. A high degree of burnout is characterized by a low score on the PA subscale. For example, a low degree of burnout is described by a PA score of 39 and above, a moderate level by a score between 32 and 38, and a low level by a score of 31 and below. PA means were 39.79 (6.23), 38.02 (6.89), 39.42 (5.58) and 39.08 (6.28) respectively. These scores indicate low levels of burnout for administrations 1 and 3 as well as over the whole semester. The score from administration 2 describes a moderate level of burnout on the PA subscale.

**Figure 1.** Percent of students at each level of EE.

**Figure 2.** Percent of students at each level of DP.

**Figure 3.** Percent of students at each level of PA.

In addition to the MBI, data was gathered through a survey. In general, the majority of students responded that:
- They received adequate emotional support from fellow ATSs.
- They did not have enough time during the day to get everything done.
- They rarely got sick.
- They had plenty of energy on most days.
- They rarely felt depressed.
- Financial concerns added to their stress level.
- They rarely had headaches.
- They understood their role at their rotation.
- They did not feel that their athletic training commitments were a waste of their time.
- Athletic training staff provided them with sufficient support and encouragement.
Their coursework adequately prepared them for their rotational experiences.
They rarely had conflicts with other ATSs.
Coaches and athletes respected them as ATSs and trusted them to help the athletes.
They rarely found their rotation boring and unchallenging.
Non-athletic training courses did not add excessive stress to their lives.
They felt that they were able to provide the same quality of care as other ATSs at their level.
Social issues (friendships, family, events, etc.) often contributed to their stress level.
Athletic training staff respected and trusted the ATSs to provide adequate care for the athletes.
They received positive feedback from coaches, athletes, athletic training staff, and fellow ATSs.
They found their coursework sufficiently challenging.

Most ATSs reported feeling overwhelmed one to two days per week, feeling tired three
to four days per week, and having problems sleeping one to two days per week. ATSs also
commonly noted that athletic training commitments interfered with their normal eating habits one to
two days per week (with the exception of administration two where most students reported this
anywhere from one to four days per week), and that they engaged in physical activity one to two
days per week (with the exception of administration one where most students reported this three
to four times per week). The majority of ATSs enjoyed helping athletes every day and never had
conflicts with coaches or athletes to add to their stress level.

In the questionnaire, ATSs were asked to rank experiences on a scale from one to twelve
describing how much the activity added to their stress level. The most common responses appear
in Table 1. On average across the three administrations, 83% of the ATSs found their rotation
challenging rather than stressful (11%). (Percentages do not add up to 100 because some students
did not respond with a single choice.)

<table>
<thead>
<tr>
<th>Admin #</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exams</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Athletic training coursework</td>
<td>2</td>
<td>2</td>
<td>2, 3</td>
</tr>
<tr>
<td>Financial concerns</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Other coursework</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Lack of free time</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Social concerns</td>
<td>6</td>
<td>5</td>
<td>4, 6</td>
</tr>
<tr>
<td>Rotation experience</td>
<td>8</td>
<td>7, 11</td>
<td>7</td>
</tr>
<tr>
<td>Family concerns</td>
<td>9</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Interacting with coaches</td>
<td>10</td>
<td>11</td>
<td>8, 11</td>
</tr>
<tr>
<td>Working with fellow ATSs</td>
<td>12</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Working with athletes</td>
<td>11</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Traveling requirements*</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

*not all student were required to travel

As the semester went on, the percent of students planning on pursuing a career in athletic
training ranged from 74.2% to 76.3%. Also, 50%, 54.8%, and 42.4% of ATSs responded in ad-
ministrations 1, 2, and 3 respectively that they planned on entering a related field (physical therapy,
occupational therapy, physician's assistant, etc.). The percent of students planning on entering an unrelated field (English, geology, etc.) was 3.2%, 3.2%, and 5.1% for administrations 1, 2, and 3 respectively. In addition, 11.3%, 9.7%, and 6.8% of ATSs were unsure if they were going to pursue a career in an unrelated field.

**Discussion**

The purpose of this study was to determine the level of burnout among athletic training students at various points throughout the fall semester. We hypothesized that the levels of burnout would be the highest during season overlap.

It is not surprising that EE and DP increased after the first administration. During season overlap, students became more stressed with the amplified amount of schoolwork and athletic training responsibilities. They often became drained and withdrawn, characteristics of EE and DP.

Overall, the descriptive data collected on the ATSs did not change much throughout the study. ATSSs also appeared to have a positive view of their experiences and programs.

In 2001 Stegler et al. measured sources of stress in Division I ATSs over the course of an academic year.\(^8\) The highest levels of behavioral (ex. procrastination) stress, cognitive stress, and somatic stress throughout the entire year took place during October.\(^8\) This corresponds with our findings showing highest levels of burnout during season overlap.

Hendrix et al. (2002) conducted a study on Division I-A certified athletic trainers working with football compared to those not working with football.\(^2\) Mean EE scores were reported at 20.24 (9.03) for football ATCs and 20.06 (8.71) for nonfootball ATCs.\(^2\) Scores of 10.93 (6.24) and 8.44 (5.20) were recorded for DP levels respectively.\(^2\) PA levels were found to be 37.15 (6.16) and 38.82 (4.60) respectively.\(^2\) The DP scores are higher in Division I-A ATCs than in Division III ATSs. In addition, Division I-A ATCs had lower levels of PA, indicating a higher degree of burnout for this subscale than Division III ATSs. These differences are not surprising because ATCSs have greater responsibility than ATSSs.

When compared to undergraduate PT students taking the MBI student version, ATSs' scores show substantially less burnout. PT students had EE scores of 23.2 (10.2), 32.7 (12.0), 34.1 (13.2), and 30.0 (11.8) at the beginning of the semester, mid-semester, end of the semester, and overall respectively.\(^1\) DP scores were reported as 7.5 (6.5), 9.0 (8.0), 9.5 (9.4), and 8.7 (7.9) respectively.\(^1\) Mean scores for PA were found to be 32.9 (6.6), 30.0 (8.4), 31.3 (7.5), and 31.4 (7.5) respectively.\(^1\) An important difference between PT students and ATSSs is PT students do not provide sports coverage and therefore, are not affected by seasons in the same way as ATSSs. PTs and OTs working in the field were found to have EE levels of 28.9 (6.8), DP levels of 18.3 (4.7), and PA levels of 18.0 (7.0).\(^6\) These values indicate burnout levels substantially higher than those reported by ATSs in this study.

This study did have limitations. The subjects provided a good representation of the selected universities, but were not representative of all ATSSs. The study also did not investigate work excitement, which has been show to correlate with burnout in other professions such as nursing.\(^9\)

Currently, there is a lack of research examining burnout in athletic training and in particular regarding ATSSs. Future studies could examine differences in burnout among ATSSs at different levels within the ATEP (second, third, and fourth years) as well as investigate burnout patterns at different ATEPs across the country and among different NCAA divisions. Methods of reducing burnout in ATSSs would also be an interesting and valuable area for further research.

**Conclusion**

Although ATSSs are stressed, they still enjoy what they do and feel they have sufficient
support from athletic training staff and students. However, burnout still appears to be an issue for athletic training students. Levels of burnout are increased during season overlap and at the end of the fall semester. ATEPs need to be aware of these burnout levels and work to minimize them.

Acknowledgements

We thank the University of Wisconsin-Eau Claire’s Office of Research and Sponsored Programs, the College of Education and Human Sciences, and the Ronald E. McNair Postbaccalaureate Achievement Program for funding this research. We also thank Dr. Jessica Kraker for her assistance with statistical analysis and Mark Gibson for his assistance with this project. This work is dedicated to the memory Dr. Jeff Oliphant who contributed to the initial stages of this project.

Appendix A. Questionnaire for Athletic Training Students.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Year in program</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>Age</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How many hours per week are you at your rotation (include the athletic training room and clinical site)?

<table>
<thead>
<tr>
<th>0-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

How many hours per week do you volunteer outside of your rotation (traveling, Special Olympics, etc.)?

<table>
<thead>
<tr>
<th>0-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Do you have a job outside of athletic training? Yes No

If so, how many hours do you work per week?

<table>
<thead>
<tr>
<th>0-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20-25</th>
<th>25-30</th>
<th>30+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How many credits are you taking this semester?

<table>
<thead>
<tr>
<th>0-11</th>
<th>12-15</th>
<th>16-19</th>
<th>20+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On average, how many hours a night do you study or practice skills?

<table>
<thead>
<tr>
<th>0-2</th>
<th>2-4</th>
<th>4-6</th>
<th>6+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How many hours a night do you sleep (on average)?

<table>
<thead>
<tr>
<th>0-4</th>
<th>4-6</th>
<th>6-7</th>
<th>7-8</th>
<th>8-9</th>
<th>9-10</th>
<th>10+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Rank the following items according to the amount of stress they cause you (12 causing the least amount stress):

- Exams
- Athletic training course work
- Working with athletes
- Financial concerns (lack of time for job, too many expenses, etc.)
- Social concerns (conflicts with friends, lack of time for social events, etc.)
- Rotation experience
- Family concerns
- Working with fellow ATSs
- Interacting with coaches
Burnout Levels in Athletic Training Students Across a Semester

- Other course work
- Lack of free time
- Traveling requirements (due to athletic training responsibilities)

Use the following scale to answer the next series of questions. Place the appropriate number in the blank provided on each line.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Applicable</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>

- I receive adequate emotional support from fellow Athletic Training Students (ATSs).
- I often feel I do not have enough time during the day to get everything done.
- I rarely get sick.
- I have plenty of energy on most days.
- I often feel depressed.
- Financial concerns often add to my stress level.
- I rarely get headaches.
- I understand my role as an ATS at my rotation.
- I feel athletic training commitments are a waste of my time.
- The athletic training staff provides me with sufficient support and encouragement.
- I feel my coursework adequately prepares me for my rotational experiences.
- I often have conflicts with other ATSs.
- Coaches and athletes respect me as an ATS and trust that I am equipped to help them.
- I often find my rotation boring and unchallenging.
- My non-athletic training related classes add excessive stress to my life.
- I often feel that I am unable to provide the same quality of care as ATSs at my level.
- Social issues (friendships, family, events, etc.) often contribute to my stress level.
- The athletic training staff respect and trust me to provide adequate care for the athletes.
- I receive positive feedback from coaches, athletes, athletic training staff, and/or fellow ATSs.
- My coursework is sufficiently challenging.

Circle the answer you feel best represents your life.

How often do you feel overwhelmed?
N/A 1-2 days/week 3-4 days/week 5-6 days/week Every day

How frequently do you feel tired?
N/A 1-2 days/week 3-4 days/week 5-6 days/week Every day

How often do you have problems sleeping?
N/A 1-2 days/week 3-4 days/week 5-6 days/week Every day

How frequently do conflicts with coaches or athletes add to your stress level?
N/A 1-2 days/week 3-4 days/week 5-6 days/week Every day

How frequently do your athletic training commitments interfere with your normal eating habits?
N/A 1-2 days/week 3-4 days/week 5-6 days/week Every day
How often do you engage in physical activity?
N/A 1-2 days/week 3-4 days/week 5-6 days/week Every day

How often do you enjoy helping athletes with their injuries?
N/A 1-2 days/week 3-4 days/week 5-6 days/week Every day

Would you consider your current rotation challenging or stressful? Challenging Stressful

Are you planning on pursuing a career in athletic training? Yes No Unsure
Are you planning on pursuing a career in a field related to athletic training (physical therapy, occupational therapy, physician's assistant, etc.)? Yes No Unsure

Are you planning on pursuing a career that is unrelated to athletic training (English, geology, etc.)? Yes No Unsure

Appendix B. Questionnaire for Program Directors.

How many years has your institution been CAATE accredited?

How many students do you have in each level?
Level 2 Level 3 Level 4 Level 5

How many athletes at your institution are under your care?

What sports does your program care for?

Are all sports offered by your university included as athletic training rotations? If not, which ones are not?

How many Certified Athletic Trainers (CATs) do you have on staff?

How many Approved Clinical sites do you have? On campus…

Would you say you are understaffed?

Does your institution use third-party reimbursement? Yes No

Please give a brief description of the responsibilities of an athletic training student (ATS) at each level (or attach a copy);
Does your program allow students to have jobs outside of the athletic training program?

What is the student to teacher ratio in the classroom?

What is the average student to Approved Clinical Instructors (ACIs) ratio, staff, etc.?

How does your program work to limit burnout among its students?

Please attach a list of courses the athletic training students must take.

References
The Moduli Space of
Three-Dimensional Lie Algebras

by

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Abstract

In this paper, we consider versal deformations of three-dimensional Lie algebras. We provide a new approach to the classification of such Lie algebras and study their deformations using linear algebra techniques to study the cohomology. We focus on how the deformations glue the space of all such structures together. We give a geometric description of this moduli space, derived from deformation theory, in order to illustrate general features of moduli spaces of Lie algebras.

1. Introduction

The classification of complex three-dimensional Lie algebras has been known for a long time, and is given in standard texts such as Jacobson [10]. There is a 1-dimensional family, which is parameterized by the unit disk (with an identification on the boundary), and 3 special algebras, one of which is given by the Lie algebra \(\mathfrak{sl}(2, \mathbb{C})\). With the exception of \(\mathfrak{sl}(2, \mathbb{C})\), the Lie algebras are given by equivalence classes of 2 x 2 matrices, up to similarity and multiplication by a complex number. From this point of view, it is natural to identify the 1-dimensional family of algebras with the diagonal matrices, and to identify the special Lie algebras as the two nonequivalent algebras given by defective matrices, one with eigenvalue 1 and the other with eigenvalue 0.

In this paper, we present a different point of view, where we use versal deformations to analyze the moduli space of 3-dimensional Lie algebras. In a recent series of papers [4, 8, 6, 1], versal deformations were used to study the structure of moduli spaces of \(L\infty\) algebras of low dimension. In [9], 3-dimensional Lie algebras were studied as \(L\infty\) algebras, and their versal deformations were constructed. These ideas were extended in [7], where the moduli space of 4-dimensional Lie algebras was analyzed. In that paper, we made an important observation about the moduli space. We discovered that it had a natural stratification in terms of orbifolds, and that the stratification is unique, in the following sense.

A 1-parameter family \(d_t\) of Lie algebras is called a jump deformation from a Lie algebra \(d\) to a Lie algebra \(d'\) if \(d_0 = d\), but \(d_t\) is equivalent to \(d'\) for all non-zero values of the parameter \(t\). On the other hand, the family is called smooth if the Lie algebras \(d_t\) are all non-isomorphic. A smooth family of deformations \(d_t\) is said to factor through a jump deformation if there is a jump deformation from \(d\) to \(d'\) and smooth families of deformations \(d_t\) and \(d'_t\), such that \(d_0 = d\), \(d'_0 = d'\) and \(d_t\) is equivalent to \(d'_t\) for all nonzero \(t\). If \(d\) has a jump deformation to \(d'\), and \(d'\) has a smooth deformation family, then \(d\) will also deform smoothly to the same family, but those deformations will factor through the jump deformation. Thus we can distinguish the smooth deformations which do not factor through a jump deformation, and these determine the stratum to which the Lie algebra belongs.

For both the 3 and 4 dimensional Lie algebras, we obtain a unique decomposition of the moduli space into orbifolds, where the neighborhoods of the points in the orbifolds are determined
by the smooth deformations which do not factor through jump deformations. In the 3-dimensional case, there is only one case which arises, where two different Lie algebras have overlapping smooth deformation families. But one of the Lie algebras has a jump deformation to the other, which means that we can determine which Lie algebra belongs to the family, uniquely. Using this idea, the decomposition we give in this paper differs from the classical decomposition only by the interchange of two points. But in the 4-dimensional case, as described in [7], the guiding principle which we just described leads to a more complicated picture.

2. Preliminaries

Here we establish the basic language in which we will express Lie algebras and their cohomology. The exterior algebra $\bigwedge V$ of an ungraded vector space $V$ has a natural $\mathbb{Z}$-grading, with $\text{deg}(v_1 \wedge \ldots \wedge v_n) = n$. There is a corresponding $\mathbb{Z}$-graded coalgebra structure with comultiplication $\Delta$ given by

$$\Delta(v_1 \wedge \cdots \wedge v_n) = \sum_{k=1}^{n-1} \sum_{\sigma \in \text{Sh}(k,n-k)} (-1)^\sigma v_{\sigma(1)} \wedge \cdots \wedge v_{\sigma(k)} \otimes v_{\sigma(k+1)} \wedge \cdots \wedge v_{\sigma(n)}.$$

Here $\text{Sh}(k,n-k)$ represents the unshuffles of type $(k,n-k)$, that is, the permutations which are increasing on $1, \ldots, k$ and $k+1, \ldots, n$, and $(-1)^\sigma$ represents the sign of the permutation $\sigma$. A linear map $\varphi \in \text{Hom}(\bigwedge^k V, V)$ has degree $k-1$; $\varphi$ can be extended to a coderivation of $\bigwedge V$ of the same degree by the rule

$$\varphi(v_1 \wedge \cdots \wedge v_n) = \sum_{\sigma \in \text{Sh}(k,n-k)} (-1)^\sigma \varphi(v_{\sigma(1)} \wedge \cdots \wedge v_{\sigma(k)}) \wedge v_{\sigma(k+1)} \wedge \cdots \wedge v_{\sigma(n)}.$$

Recall that a coderivation of $\bigwedge V$ is a linear map $\varphi : \bigwedge V \to \bigwedge V$ satisfying $\Delta \varphi = (\varphi \otimes 1 + 1 \otimes \varphi) \Delta$. We can view $L^* = \text{Hom}(\bigwedge^* V, V)$ as a subspace of the space $L = \text{Coder}(\bigwedge V)$. Moreover $L = \prod_{k=0}^{\infty} L^k$ in a natural way. The space of coderivations of $V$ has a natural structure of a $\mathbb{Z}$-graded Lie algebra. If $\varphi \in L^k$ and $\psi \in L^l$ then $[\varphi, \psi] \in L^{k+l+1}$ is given by $[\varphi, \psi] = \varphi \psi - (-1)^{\deg \varphi \deg \psi} \psi \varphi$. More explicitly, we compute

$$(\varphi \psi)(v_1 \wedge \cdots \wedge v_{k+l-1}) = \sum_{\sigma \in \text{Sh}(k,l-1)} (-1)^\sigma \varphi(\psi(v_{\sigma(1)} \wedge \cdots \wedge v_{\sigma(l)})) \wedge v_{\sigma(l+1)} \wedge \cdots \wedge v_{\sigma(k+l-1)},$$

which determines $\varphi \psi$ as an element of $L^{k+l}$.

If $V = \mathbb{F}^d$, $i_1 \ldots N >$ and $I = (i_1, \ldots, i_j)$ is an increasing multiindex; i.e., $1 \leq i_1 < \ldots < i_j \leq N$, then $\varphi^I_k \in L^k$ is defined by $\phi^k_I(f) = \delta^I_k f$, where $f = f_{i_1} \wedge \ldots \wedge f_{i_j}$. Then we have

$$L^k = \langle \varphi^I_k | 1 \leq i_1 < \cdots < i_k \leq N, 1 \leq j \leq N \rangle, \quad \dim(L^k) = \binom{N}{k}.$$

When $k$ is odd, the elements in $L^k$ are called even and when $k$ is even the elements in $L^k$ are odd.

To emphasize the difference, we will denote the basis elements of $L^k$ in the form $\varphi^I_j$ rather than $\varphi^I_j$. It is not difficult to give an explicit formula for the brackets of the coderivations in terms of the basis $\varphi^I_j$.

An element $d$ is called a codifferential if $d^2 = 0$, or equivalently $[d, d] = 0$, since $[d, d] = 2d^2$. If $d$ is in $L^2$, the condition $d^2 = 0$ is the Jacobi identity

$$d(d(a, b), c) - d(d(a, c), b) + d(d(b, c), a) = 0,$$

and therefore a codifferential in $L^2$ is just a Lie algebra structure on $V$. 

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The coboundary operator $D : L \to L$ determined by $d$ is given by $D(\varphi) = [d, \varphi]$. The fact that $D$ is a differential on $L$ (in other words, that $D^2 = 0$) follows immediately from the fact that $d$ is a codifferential. Then $H(d) = \ker(d) / \text{Im}(d)$ is called the cohomology of $d$. If $d \in L^2$, then $[d, L^1] \subseteq L^{k+1}$, and thus we can define the $k^\text{th}$ cohomology group

$$H^k(d) = \ker(d : L^k \to L^{k+1}) / \text{Im}(d : L^{k-1} \to L^k).$$

Then $H(d) = \prod_{k=1}^{\infty} H^k(d)$.

It is useful to have an explicit formula for the $n^\text{th}$ element of an ordered basis of $\bigwedge^k V$. If we define the ordered $k$-tuple $S(n, k)$ recursively by $S(n, 1) = (n)$ and for $k > 1$, we define

$$S(n, k) = \left( S \left( n - \binom{l-1}{k} \right), k - 1, l \right),$$

where $l$ is determined by the requirement that $\binom{l-1}{k} < n \leq \binom{l}{k}$, then $f_S(n, k)$ is the $n^\text{th}$ element of $\bigwedge^k V$ for $1 \leq n \leq \binom{N}{k}$. In the formula above, the right-hand side is an ordered pair consisting of the $(k-1)$-tuple $S(n - \binom{l-1}{k}, k-1)$ and the number $l$, so we can identify $S(n, k)$ as a $k$-tuple.

Any coderivation in $L^k$ can be expressed in the form

$$\varphi = a^{j}_{ij} f_{S(j,i)}$$

using the Einstein summation convention. We can therefore represent $\varphi$ by the $\binom{N}{k}$ matrix $A = (a^{j}_{ij})$. More generally, $\varphi : L^m \to L^{m+k+1}$ is represented by the $\binom{N}{m+k+1}$ matrix $B = (b_{ij})$, where

$$\varphi(f_{S(i,m)}) = b_{ij} f_{S(i,m-k+1)}.$$

In particular when $m = 2k - 1$ the matrix $AB$ represents $\varphi^2$. Thus $\varphi^2 = 0$ is equivalent to the matrix equation $AB = 0$. Moreover, if $d = a^{j}_{ij} f_{S(j,i)} \in L^2$ is a codifferential, then the Jacobi identity is equivalent to $AB = 0$. The coefficients $b_{ij}$ can be determined as follows. It is easy to see that

$$\varphi^{(u,v)}(f_{(r,s,t)}) = [\delta^u_{r} \delta^v_{s} (\delta^k_{w} \delta^l_{t} - \delta^k_{t} \delta^l_{w}) - \delta^u_{r} \delta^v_{t} (\delta^k_{w} \delta^l_{s} - \delta^k_{s} \delta^l_{w}) + \delta^u_{s} \delta^v_{t} (\delta^k_{w} \delta^l_{r} - \delta^k_{r} \delta^l_{w})] f_{(k,l)}.$$

Suppose that

$$S(j, 3) = (r, s, t)$$

$$S(i, 2) = (k, l).$$

Then

$$b_{ij} = a^{w}_{S^{-1}(u,v)} [\delta^u_{r} \delta^v_{s} (\delta^k_{w} \delta^l_{t} - \delta^k_{t} \delta^l_{w}) - \delta^u_{r} \delta^v_{t} (\delta^k_{w} \delta^l_{s} - \delta^k_{s} \delta^l_{w}) + \delta^u_{s} \delta^v_{t} (\delta^k_{w} \delta^l_{r} - \delta^k_{r} \delta^l_{w})].$$

The above formula is essentially implemented on a computer and determines the coefficients $B$ linearly in terms of the coefficients of $A$. Since $AB$ is an $N \times \binom{N}{3}$ matrix, this means the Jacobi identity is given by $\binom{N}{3}$ homogenous quadratic equations in the $\binom{N}{3}$ coefficients of $A$.

An invertible linear map $g : V \to V$ extends to a coalgebra automorphism of $\bigwedge V$ by $g(\varphi^{\wedge^k} V^\wedge) = g(\varphi)^{\wedge^k} V^\wedge$. Two Lie algebra structures are isomorphic, or in other words, their associated codifferentials $d, d'$ are equivalent, if there is an invertible linear map $g : V \to V$ such that $g^* (d') = g^* (d) \circ d' \circ g = d'$. The set of equivalence classes of codifferentials on $V$ is called the moduli space of Lie algebra structures on $V$.

Let $G = (g_{ij})$ where $g(\varphi^{(i,j)}) = g_{ij} f_{S(i,j)}$ represents $g : V \to V$ as an $N \times N$ matrix. Define the $\binom{N}{2} \times \binom{N}{2}$ matrix $Q = (Q_{ij})$ by $g(\varphi_{S(j,i)}) = Q_{ij} f_{S(j,i)}$ so that $Q$ represents $g : \bigwedge^2 V \to \bigwedge^2 V$. Suppose that
\[ S(j, 2) = (u, v) \]
\[ S(i, 2) = (k, l). \]

Then
\[ q^{ij}_j = g^k_v g^l_i - g^l_v g^k_i. \]

If \( A \) (respectively, \( A' \)) represent the codifferential \( d \) (respectively, \( d' \)), the condition \( g^*(d) = d' \) is represented by the matrix equation \( A = G^1AQ \). It is easier to solve the equation \( GA' = AQ \) and to check whether the solution matrix \( G \) satisfies \( \det G \neq 0 \).

3. Three-Dimensional Lie Algebras

Let \( V = \langle f_1, f_2, f_3 \rangle \) be a three-dimensional vector space with Lie algebra structure determined by the codifferential \( d \) which is represented by the \( 3 \times 3 \) matrix \( A = (a^{ij}_j) \). Then if
\[ B = \begin{bmatrix} -a_{1,2} - a_{2,3} & 0 \\ a_{1,1} - a_{3,3} & 0 \\ a_{2,1} + a_{3,2} & 0 \end{bmatrix}, \]

the Jacobi identity is equivalent to the matrix equation \( AB = 0 \).

Recall that the derived subalgebra of a Lie algebra is the image of \( d : S^2(V) \to V \). Since \( A \) is a matrix representing \( d \) it follows that the rank of \( A \) is the dimension of the derived subalgebra.

We first consider the case where the derived subalgebra has dimension three. Then the matrix \( A \) of \( d \) is invertible, and thus it must be the case that \( B = 0 \). In [7], it is shown that any \( n \) dimensional Lie algebra structure such that the bracket of any two elements is a linear combination of those elements has an abelian ideal of dimension \( n - 1 \). We shall see that whenever there is an ideal of dimension \( n - 1 \) the rank of the associated matrix can never be larger than \( n - 1 \). Thus by choosing an appropriate basis we may assume that \( d(\langle f_2, f_3 \rangle) = f_5 \). Taking into account the fact that \( B = 0 \) we see that the matrix \( A \) has to be of the form
\[ A = \begin{bmatrix} 0 & x & y \\ 0 & z & -x \\ 1 & 0 & 0 \end{bmatrix} \]
where \( x^2 + yz \neq 0 \).

It is easy to see that \( d \) is equivalent to a codifferential whose matrix is of the form \( A' = \begin{bmatrix} 0 & 0 & 0 \\ 0 & \beta & 0 \\ 1 & 0 & 0 \end{bmatrix} \). In fact, if \( z \neq 0 \), then the linear automorphism \( g \) whose matrix is \( G = \begin{bmatrix} 0 & 0 & -x \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{bmatrix} \) yields \( A' = G^1AQ \), where \( \beta = x^2 + yz \), \( \eta = z \); if \( y \neq 0 \) then \( G = \begin{bmatrix} 0 & 0 & -x \\ 0 & 1 & \frac{x}{y} \\ 1 & 0 & 0 \end{bmatrix} \) gives \( \beta = y, n = -x^2 - yz \); while if both \( y \) and \( z \) vanish then \( G = \begin{bmatrix} 0 & 0 & -x \\ 0 & 1 & \frac{1}{x} \\ 1 & 0 & 0 \end{bmatrix} \) gives \( \beta = \eta = x \).

It follows that any codifferential whose matrix is invertible is equivalent to one whose matrix is of the form \( A = \begin{bmatrix} 0 & 0 & \mu \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \). The automorphism determined by \( G = \text{Diag}(r, s, r) \) preserves the form of \( A \) with \( \lambda \to \lambda' = r\lambda, \mu \to \mu' = r\mu \), which is enough to see that there is only one equivalence class of codifferentials with invertible matrix over \( \mathbb{C} \). Moveover \( G = \begin{bmatrix} 0 & -1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \) preserves the form as well, with \( \lambda \to \lambda' = -\mu, \mu \to \mu' = -\lambda \), which shows that there are at most two nonequivalent such codifferentials over \( \mathbb{R} \). Of course, these two codifferentials correspond to the two nonequivalent compact real forms of the simple complex Lie algebra \( \mathfrak{sl}_2(\mathbb{C}) \).

Now suppose that the derived algebra of a Lie algebra on a vector space \( V \) of dimension \( n \) has dimension smaller than \( n \). Then there is an ideal \( V' \subset V \) of dimension \( n - 1 \). This gives rise to
the exact sequence

\[ 0 \to V' \to V \to C \to 0, \]

where \( C \) is the trivial lie algebra. Let \( d' \) be the induced codifferential on \( V' \); given by \( d'(u, v) = d(u, v) \) for \( u, v \in V' \), with matrix \( A' \) in terms of the basis \( \{ f_1, \ldots, f_{n-1} \} \) of \( V' \). Let \( \{ f_n \} \) be a basis of a complementary subspace to \( V' \) and define \( \rho : V' \to V' \) by \( \rho(u, v) = d(u, f_2) \). Then \( \rho \) is a derivation of \( d' \), in other words \( \rho d'(u, v) = d'(\rho(u), v) + d'(u, \rho(v)) \). If \( R = \{ r_i^j \} \) is the matrix of \( \rho \), given by \( \rho(f_j) = r_j^i f_i \), then the matrix of \( A \) is just \( A = \begin{bmatrix} A' & 0 \\ 0 & \rho \end{bmatrix} \).

If \( f'_n = f_n' + v \), where \( v \in V' \), then the induced derivation \( \rho(u, v) = d(u, f_n') \) determines an equivalent coderivation to \( d \). Moreover, \( \rho'(u) = \rho(u) + \text{ad}_v(u) \), where \( \text{ad}_v(u) = d(u, v) \) is the inner derivation of \( V' \) determined by \( v \). Thus we can replace \( R \) by the matrix \( \rho' \) given by \( \rho' \), and we see that the extensions of \( V' \) by \( C \) are determined by the space of outer derivations \( \text{Out}(d') \) of the induced Lie algebra structure on \( V' \). If we denote the space of inner derivations of \( V' \) by \( \text{ad}(d') \), then \( \text{Out}(d') = \mathcal{Z}(d') = \text{ad}(d') = \mathcal{H}(d') \).

Now let us specialize this to the three-dimensional case of Lie algebras. We use the fact that there are, up to equivalence, only two Lie algebra structures on a two dimensional vector space.

Case 1. The nonabelian Lie algebra, given by \( d(f_1, f_2) = f_3 \).
Case 2. The abelian Lie algebra, given by \( d(f_1, f_2) = 0 \).

Let us study the possible forms for the matrix \( R \) in case 1. We have

\[
\begin{align*}
    r_1^1 f_1 + r_2^1 f_2 &= \rho(f_1) = \rho(d(f_1, f_2)) = d(\rho(f_1), f_2) + d(f_1, \rho(f_2)) \\
    &= d(r_1^1 f_1 + r_2^1 f_2, f_2) + d(f_1, r_2^1 f_1) = r_1^1 f_1 + r_2^1 f_2.
\end{align*}
\]

It follows that \( r_1^2 = r_2^2 = 0 \). Consider the inner derivations \( \rho_1(u) = d(u, f_2) \).

It is easy to see that \( \rho = -r_1^1 \rho_1 + r_2^2 \rho_2 \). Thus every derivation is inner, and we may assume that \( R = 0 \). But then \( \{ f_1 \} \) span an ideal on which \( d \) acts as the zero matrix. Thus, the nonabelian case reduces to the abelian one.

Now assume that \( d' = 0 \). Then \( d \) is represented by the matrix \( A = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \), where \( R \) is any \( 2 \times 2 \) matrix. However, if \( G' \) is any linear automorphism of \( V' \) given by a matrix \( G' \), and \( g \) is the linear automorphism of \( V \) given by the matrix \( G = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \), then \( d \) can also be represented by the matrix \( A' = \begin{bmatrix} G & 0 \\ 0 & R' \end{bmatrix} \), where \( R' = (G0)^{-1}RG' \). Thus similar matrices \( R \) determine equivalent codifferentials. Moreover, multiplication of \( R \) by any nonzero constant \( \lambda \) also determines an equivalent codifferential, corresponding to the linear automorphism given by the matrix \( G = \text{Diag}(1, 1, \lambda) \).

As a consequence, we immediately reduce to the following possibilities.

\[ d(\lambda : \mu) \]

\[
\begin{cases}
    \text{given by the matrix } R = \begin{bmatrix} \lambda & 0 \\ 0 & \lambda \end{bmatrix}, & \text{Note that } R \text{ is similar to the matrix } \begin{bmatrix} 1 & \lambda \\ 0 & 1 \end{bmatrix}, \text{ and thus } d(\mu : \lambda) \sim d(\lambda : \mu). \text{ Moreover, if we consider the linear automorphism determined by the diagonal matrix } G = \text{Diag}(t, 1, 1), \text{ then } R \text{ is replaced by the matrix } \begin{bmatrix} t & 0 \\ 0 & t \end{bmatrix}, \text{ and thus } d(\lambda : \mu) \sim d(\lambda : \mu). \text{ As a consequence, we can view } (\lambda : \mu) \in P^1. \text{ The similarity of matrices with the same eigenvalues determines an action of } \Sigma_2 \text{ on } P^1, \text{ and therefore the set of codifferentials of this type are parameterized by the orbifold } P^1/\Sigma_2. \\
    \end{cases}
\]

\[ d_2: \]

\[
\begin{cases}
    \text{given by the matrix } R = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}, & \\
    \end{cases}
\]

\[ d_3: \]

\[
\begin{cases}
    \text{given by the matrix } R = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}, & \\
    \end{cases}
\]

Together with the codifferential \( d_3 \) representing the Lie algebra structure \( \text{sl}_2(\mathbb{C}) \) these codifferentials represent a complete classification of all three-dimensional Lie algebras. The codif-
ferential \( d \), represents the Heisenberg algebra \( \mathfrak{h}_3(\mathbf{C}) \), \( d(0 : 1) \) represents the Lie algebra \( \mathfrak{h}_2(\mathbf{C}) \oplus \mathbf{C} \), \( d(1 : 1) \) represents the solvable Lie algebra \( \mathfrak{h}_3(\mathbf{C}) \), while \( d(\lambda : \mu) \) represents the solvable Lie algebra \( \mathfrak{h}_{3, \mu / \lambda}(\mathbf{C}) \) when \( \lambda \neq \mu \). Note that our alignment of algebras into families differs slightly from the classical alignment. If we interchange \( d \) with \( d(1 : 1) \) then the alignment would agree, but our reasons for not making this change will become apparent.

4. Miniversal Deformations of Lie Algebras

The classical notion of an infinitesimal deformation of a Lie algebra structure on a vector space \( V \) given by a codifferential \( d \in \Omega^2 \) is a coderivation
\[
d_e = \delta + t \psi,
\]
where \( \psi \in \Omega^2 \), which satisfies the Jacobi identity infinitesimally; i.e., \([d_e, d] = 0 \bmod t^2\). The condition is equivalent to \( D(\psi) = 0 \), where \( D : \Lambda \to \Omega \) is the coboundary operator determined by \( d \). Let \( \mathcal{A} = \mathbb{C}[x] \). Then \( \mathcal{A} \) is a local algebra, with maximal ideal \( \mathfrak{m} = (d) \). We can consider \( d \) as being an element of \( L \otimes \mathcal{A} \), which may be thought of as the coderivations of \( \Lambda(V) \) with coefficients in \( \mathcal{A} \). In this sense, \([d_e, d] = 0 \) in terms of the natural bracket on \( L \otimes \mathcal{A} \).

One can generalize this construction by allowing \( \mathcal{A} \) to be any local (commutative) algebra over \( \mathbb{C} \), and say that \( d_A \in L \otimes \mathcal{A} \) is a deformation of \( d \) with local base \( \mathcal{A} \) if \( \epsilon_\mathcal{A}(d_A) = d \), where \( \epsilon : \mathcal{A} \to \mathbb{C} \) is the augmentation homomorphism, and \( \epsilon_* : L \otimes \mathcal{A} \to L \otimes \mathbb{C} = L \) is the induced map.

If \( \mathfrak{m}^2 = 0 \), then we call \( \mathcal{A} \) an infinitesimal algebra, and say that \( d_A \) is an infinitesimal deformation. This notion of infinitesimal deformation generalizes the classical notion. An infinitesimal deformation \( d_A \) with base \( \mathcal{A} \) is universal if whenever \( d_B \) is an infinitesimal deformation with base \( B \), then there is a unique homomorphism \( f : \mathcal{A} \to B \) such that \( f_* (d_A) \sim d_B \), where \( \sim \) means infinitesimal equivalence. Two deformations \( d_B \) and \( d_C \) with the same base \( B \) are said to be infinitesimally equivalent if there is an infinitesimal automorphism \( g_B \in \text{Aut}(V) \otimes B \), satisfying \( g_B^*(d_B) = d_C \). We say that \( g_B \) is an infinitesimal automorphism if \( \epsilon_\mathcal{A}(g_B) = 1_V \).

If \( \dim(\text{HP}(d)) = n \), then the deformation \( d^\inf \), with base \( \mathcal{A} = \mathbb{C}[x^1, \ldots, x^n] \), given by
\[
d^\inf = \delta + \delta_it^i,
\]
where \( \{\delta_i\} \) is a prebasis of \( \text{HP}(d) \), is a universal infinitesimal deformation. The classical notion of a formal deformation is given by a power series
\[
d_e = \delta + \psi_it^i,
\]
where \( \psi_i \in \Omega^2 \) and \([d_e, d] = 0 \). We may consider \( d_e \in \Lambda \otimes \mathcal{A} \), where \( \mathcal{A} = \mathbb{C}[[t]] \) is the ring of formal power series in the variable \( t \), and \( \otimes \) means the formal completion of the tensor product \( L \otimes \mathcal{A} = \lim_{k \to \infty} L \otimes A/m^k \), where \( m = (\delta) \). More generally, we say that \( \mathcal{A} \) is a formal algebra if \( \mathcal{A} = \lim_{k \to \infty} A/m^k \), and say that a codifferential \( d_A \in L \otimes \mathcal{A} \) is a formal deformation of \( d \) if \( \epsilon_\mathcal{A}(d_A) = d \). There is no universal formal deformation of \( d \), but there is a similar notion called a versal deformation.

A formal deformation \( d_A \) with base \( \mathcal{A} \) is versal if given any formal deformation \( d_B \) with base \( B \), there is a homomorphism \( f : \mathcal{A} \to B \) such that \( f_* (d_A) \sim d_B \); in other words, it is the same condition as for a universal deformation with the exception that we drop the uniqueness requirement for \( f \). If \( f \) is unique whenever \( B \) is an infinitesimal algebra, then \( d_A \) is called a mini-
versal deformation of \( d \). In [2], it was shown that miniversal deformations exist whenever \( \dim(H^p(d)) < \infty \). To see how to construct the miniversal deformation, we proceed as follows.

Let us identify \( H^p(X) \) with a preimage in \( L^p \), then the space \( Z^p \) of \( n \)-cocycles decomposes as \( Z^p = H^p \oplus B^p \), where \( B^p = D(L^p) \) is the space of \( n \)-coboundaries. Let us also choose some preimages \( P^{n+1} \) of \( B^n \), and thus \( P^n \subseteq L^n \). Choose some bases \( \{ \delta_i \} \) of \( H^p \) and \( \{ \alpha_i \} \) of \( H^p \). Since \( H^p \) is finite dimensional, we can define

\[
d^1 = d + \delta_i t^i,
\]

where the \( t^i \) are parameters (not powers), which we think of as elements of the local ring \( \mathbb{C}[t^i]/m \), where \( m = (t^i) \) is the ideal generated by the \( t^i \).

Note that

\[
[d^3, d^1] = [\delta_i, \delta_j] t^i t^j \in Z^3 \otimes m^2.
\]

Thus

\[
[d^3, d^1] = \alpha_i r^i_2 + \beta_2,
\]

where \( r^i_2 \in m^2 \) and \( \beta_2 \in B^3 \otimes m^2 \). Now, \( \beta = 2Dy_2 \) for some \( \gamma_2 \in P^2 \otimes m^2 \), and let \( d^2 = d + \gamma_2 \).

Let \( R_2 = (r^2_2) \) be the ideal generated by the \( r^2_2 \). Then

\[
[d^2, d^3] = [d^1, d^1] = 2[d^1, \gamma_2] + [\gamma_2, \gamma_2]
\]

\[
= \alpha_i r^i_2 + 2d - d + [\gamma_2, \gamma_2]
\]

\[
= \alpha_i r^i_2 + 2d - d + [\gamma_2, \gamma_2]
\]

\[
\in H^3 \otimes R_2 + L^3 \otimes m^3 + L^3 \otimes m^4 \subseteq L^3 \otimes (R_2 + m^3).
\]

Moreover,

\[
D[d^2, d^3] = -2[d^1, d, D\gamma_2] + 2[D\gamma_2, \gamma_2]
\]

\[
= [d^1, d, \beta_2] + 2[D\gamma_2, \gamma_2]
\]

\[
= [d^1, \beta_2] + 2[D\gamma_2, \gamma_2]
\]

\[
= [d^1, d^1] - [d^1, \alpha r^i_2] + 2[D\gamma_2, \gamma_2]
\]

\[
= [-d^1, d, \alpha r^i_2] + 2[D\gamma_2, \gamma_2]
\]

\[
\in Z^3 \otimes m R_2 + L^4 \otimes m^4 \subseteq L^4 \otimes (m R_2 + m^4).
\]

Since \( D[d^2, d^3] \in B^4 \otimes \mathbb{C}[[t^i]] \), it follows that \( D[d^2, d^3] \in B^4 \otimes (m R_2 + m^4) \). Thus

\[
[d^2, d^3] = \alpha_i r^i_3 + \beta_3 + \tau_3,
\]

where we have \( r^i_3 - r^i_2 \in m^3, \beta_3 \in B^3 \otimes m^3 \) and \( \tau_3 \in P^3 \otimes (m R_2 + m^4) \). If \( R_3 \) is the ideal generated by \( r^i_3 \), then \( m R_2 \subseteq R_3 + m^4 \), and thus \( \tau_3 \in P^3 \otimes (R_3 + m^4) \). Now suppose inductively that we have been able to construct \( d^p \) satisfying

\[
[d^p, d^{p+1}] = \alpha r^i_{p+1} + \beta_{p+1} + \tau_{p+1},
\]

where we have \( r^i_{p+1} - r^i_p \in m^{p+1}, \beta_{p+1} \in B^3 \otimes m^{p+1} \), \( R_{p+1} = (r^i_{p+1}) \) and \( \tau_{p+1} \in P^3 \otimes (R_{p+1} + m^{p+2}) \). Then \( 2\beta_{p+1} = -Dy_{p+1} \) for some \( \gamma_{p+1} \in P^2 \otimes m^{p+1} \), we have

\[
[d^{p+1}, d^{p+1}] = [d^p, d^{p+1}] + [\gamma_{p+1}, \gamma_{p+1}]
\]

\[
= \alpha r^i_{p+1} + \tau_{p+1} + 2[d^p - d, \gamma_{p+1}] + [\gamma_{p+1}, \gamma_{p+1}]
\]

\[
\in H^3 \otimes R_{p+1} + P^3 \otimes (R_{p+1} + m^{p+2}) + L^3 \otimes m^{p+2}.
\]

Note that \( L^3 \in H^3 \otimes (R_{p+1} + m^{p+2}) \), and thus the coboundary part in the above lies strictly in \( B^3 \otimes m^{p+2} \). Now
The Moduli Space of Three-Dimensional Lie Algebras

\[ D[d^{n+1}, d^{n+1}] = [d, \tau_{n+1}] + 2[D(d^n), \gamma_{n+1}] - 2[d^n - d, D\gamma_{n+1}] \\
+ 2[D\gamma_{n+1}, \gamma_{n+1}] \\
= [d^n, \tau_{n+1}] + [d - d^n, \tau_{n+1}] + 2[D(d^n), \gamma_{n+1}] + [d^n, \beta_{n+1}] \\
+ 2[D\gamma_{n+1}, \gamma_{n+1}] \\
= -[d^n, \alpha_i r_{n+1}^i] + [d - d^n, \tau_{n+1}] + 2[D(d^n), \gamma_{n+1}] \\
+ 2[D\gamma_{n+1}, \gamma_{n+1}] \\
\subseteq H^3 \otimes \mathfrak{m} R_{n+1} + L \otimes (\mathfrak{m} R_{n+1} + m^{n+3}) + L \otimes m^{n+3} \\
\subseteq L^3 \otimes (\mathfrak{m} R_{n+1} + m^{n+3}) .
\]

Consequently, we can express

\[ [d^{n+1}, d^{n+1}] = \alpha_i r_{n+2}^i + \beta_{n+2} + \tau_{n+2}, \]

where \( r_{n+2}^i - r_{n+1}^i \in m^{n+2}, \beta_{n+2} \in B^3 \otimes m^{n+2}, R_{n+2} = (r_{n+2}^i), \) and \( \tau_{n+2} \in P^2 \otimes (\mathfrak{m} R_{n+1} + m^{n+3}) \subseteq P^2 \otimes (R_{n+1} + m^{n+3}). \) Thus we can continue the construction indefinitely, and we obtain finally a deformation

\[ d^\infty = d + \sum_{i=2}^{\infty} \gamma_i, \]

which satisfies \([d^\infty, d^\infty] = \alpha_i r_i^i,\) where \( r_i^i = \lim_{n \to \infty} r_n^i \) give the relations on the base of the miniversal deformation. If we let \( R_\infty = (r_i^i), \) and take \( \mathcal{A} = \mathbb{C}[t^i]/R_\infty \) in \( L \otimes \mathcal{A}, \) and \( d^\infty \) is a miniversal deformation of \( d \) with base \( \mathcal{A}. \) (See [3] for a proof that \( d^\infty \) is miniversal).

The process described above is not very efficient in constructing the miniversal deformation, because it potentially requires an infinite number of steps, although, in practice, it often terminates after a finite number of steps. In some recent papers [9, 5, 8, 6, 7, 1], the authors have shown how to construct a miniversal deformation \( d^\infty \) as follows.

\[ d^\infty = d + \delta_i t_i + \gamma_i x_i, \]

where \( \{\delta_i\} \) is a prebasis of \( \mathcal{H}^p(d), \) \( \{\gamma_i\} \) is a basis of \( P^2, \) \( t^i \) are the parameters which appear in the base \( \mathcal{A}, \) and \( x^i \) are formal power series in the parameters \( r^i \) which are found as follows. To determine the coefficients \( x^i, \) we compute

\[ [d^\infty, d^\infty] = \alpha_i r_i^i + \beta_i s_i^i + \tau_i y_i^i, \]

where \( \{\alpha_i\} \) is a basis of \( \mathcal{H}^p, \{\beta_i\} \) is a basis of \( B^3, \) and \( \{\tau_i\} \) is a basis of \( P^0. \) Thus, taken together, the \( \alpha_i, \beta_i, \tau_i \) give a basis of \( L^3. \) By the construction of the miniversal deformation given in [3], it follows that \( \delta_i = 0 \) for all \( i, \) \( \tau^i \) are formal power series in the parameters \( r^i, \) and \( y_i = 0 \mod (r^i, \ldots). \) Moreover, the equations \( \delta_i = 0 \) can be solved to obtain the expressions for \( x^i \) as formal power series in the parameters \( r^i. \) Actually, the \( x^i \) can always be expressed as rational functions of the parameters.

The construction above can be implemented on a computer, and we have constructed Maple worksheets that carry out this implementation for an arbitrary finite dimensional Lie algebra. Using these programs we have constructed miniversal deformations of all 3-dimensional Lie algebras, which we give below. We will also give prebases for the cohomology for each of these examples.

Note that the construction of the miniversal deformation depends on the choices of the bases and prebases above. For 3-dimensional Lie algebras, it is always possible to find a choice for which the infinitesimal deformation is miniversal; in other words, one can take the \( x^i \) to vanish. However, for other choices of bases of \( H^3, \) the miniversal deformation will have an infinite number of terms.
5. Calculation of the Miniversal Deformations

<table>
<thead>
<tr>
<th>Type</th>
<th>Codiff</th>
<th>$H^1$</th>
<th>$H^2$</th>
<th>$H^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_1 = n_3$</td>
<td>$\psi_1^{23}$</td>
<td>4</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>$d_2 = r_{3,1}(\mathbb{C})$</td>
<td>$\psi_1^{13} + \psi_2^{23}$</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>$d(1 : 1) = r_{3}(\mathbb{C})$</td>
<td>$\psi_1^{13} + \psi_2^{23} + \psi_3^{33}$</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$d(\lambda : \mu) = r_{3,\mu/\lambda}(\mathbb{C})$</td>
<td>$\psi_1^{13} \lambda + \psi_2^{23} \mu + \psi_3^{33} \mu\lambda$</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$d(1 : 0) = r_2(\mathbb{C}) \oplus \mathbb{C}$</td>
<td>$\psi_1^{13} + \psi_2^{23}$</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$d(1 : -1) = r_{3,-1}(\mathbb{C})$</td>
<td>$\psi_1^{13} + \psi_2^{23} - \psi_3^{33}$</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>$d_3 = s_2(\mathbb{C})$</td>
<td>$\psi_1^{13} + \psi_2^{23} + \psi_3^{33}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1. Cohomology of Three-Dimensional Algebras

Table 1 gives the cohomology for each of the types of 3-dimensional Lie algebras. Note that for Lie algebras of type $d(\lambda : \mu)$ there are two special values of the parameters. For $d(1 : 0)$ the only variation is in $H^1$, which plays no role in the miniversal deformation. For $d(1 : -1)$, $H^2$ and $H^3$ are not the same as for generic elements of the family $d(\lambda : \mu)$; this difference plays an important role in understanding the moduli space.

5.1. The codifferential $d_1$. From Table 1 we see that $H^3(d_1) = 0$, and therefore there are no deformations of this codifferential. This is not surprising, as this codifferential corresponds to the simple Lie algebra $\mathfrak{s}_4(\mathbb{C})$. As we shall see, some of the other codifferentials can deform into $d_1$.

5.2. The codifferential $d(\lambda : \mu)$, $\mu \neq \lambda$. For generic values of $(\lambda : \mu)$ we have

\[ H^1 = \langle \varphi_1^1 + \varphi_2^2 \rangle \]
\[ H^2 = \langle \psi_2^{13} \rangle. \]

The universal infinitesimal deformation is

\[ d^1 = \psi_1^{13} \lambda + \psi_2^{23} \mu + \psi_3^{33} \mu. \]

Because $[d^1, d^2] = 0$, the universal infinitesimal deformation is miniversal. Since $H^3 = 0$ there can be no relations on the base, which is therefore $A = \mathbb{C}[\{t\}]$. The matrix of the miniversal deformation is

\[ A = \begin{bmatrix} 0 & \lambda & 1 \\ 0 & t^1 & \mu \\ 0 & 0 & 0 \end{bmatrix}. \]

This matrix is just the matrix of $d(\lambda : \mu)$ where

\[ \alpha, \beta = \frac{\lambda + \mu \pm \sqrt{(\lambda - \mu)^2 + 4t^1}}{2}. \]

Thus deformations of $d(\lambda : \mu)$ are simply smooth deformations along the family. We see that there are no jump deformations. The codifferential $d(1 : 1)$ has no special behavior in this context so it is more natural to include it in the family than $d_1$, which as we will see later has a more complicated deformation picture.

5.3. The codifferential $d(1 : 0)$. The only special thing about $d(1 : 0)$ is that $H^3$ is 2-dimensional. We have

\[ H^1 = \langle \varphi_1^1 + \varphi_2^2 \rangle. \]

The significance of this is that there are more outer derivations of $d(1 : 0)$, which plays a role in con-
sidering extensions of a Lie algebra by the algebra corresponding to \( d(1 : 0) \). The deformation picture is generic which implies that deformations of \( d(1 : 0) \) are just smooth deformations along the family. This justifies our unconventional inclusion of this element in the one parameter family of Lie algebras.

5.4. The codifferential \( d(1 : -1) \). We have

\[
H^1 = (2\varphi_1 + \varphi_2^2) \\
H^2 = \psi_1^{13} + \psi_3^{12} \\
H^3 = (\varphi_3^{123}).
\]

The universal infinitesimal deformation is

\[
d^1 = \psi_1^{13}(1 + t^1) + \psi_2^{13} - \psi_3^{23} + \psi_3^{12} t^2.
\]

This deformation also coincides with the miniversal deformation \( d^\infty \), but in this case, we do have one relation on the base

\[
t^1 t^2 = 0,
\]

and thus the base of the miniversal deformation is \( A = \mathbb{C}[[t', t]]/(t't') \). This relation follows from the bracket calculation

\[
[d^\infty, d^\infty] = -2\varphi_3^{123} t^1 t^2.
\]

In order to study the deformations, we have to take into account the relation. Thus, in the matrix

\[
A = \begin{bmatrix} 0 & 1 & t^1 & 1 \\ 0 & 0 & -1 \\ t^2 & 0 & 0 \end{bmatrix}
\]

of the miniversal deformation, we must either have \( t' = 0 \), or \( t' = 0 \). This means that although the tangent space \( H^2 \) is 2 dimensional, the actual deformations only occur along two curves.

Along the curve \( t' = 0 \), \( d^\infty \sim d_3 \). In fact, if we let \( g \) be the automorphism of \( \mathbb{C}^3 \) whose matrix \( G \) is given by

\[
G = \begin{bmatrix} 0 & -1/2 & 1/2 t^2 \\ 0 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix},
\]

then \( d_3 = g^*(d^\infty) \). Thus we have a jump deformation from \( d(1 : -1) \) to \( d_3 \) along this curve.

Along the curve \( t^2 = 0 \), we have \( d^\infty = d(1 + t^1, -1) \), which gives a smooth deformation along the family. Thus the picture for \( d(1 : -1) \) is more interesting.

5.5. The codifferential \( d_2 \). We have

\[
H^1 = (\varphi_1 + \varphi_2^2, \varphi_2^2) \\
H^2 = \psi_1^{13} + \psi_3^{13}.
\]

The universal infinitesimal deformation is

\[
d^1 = \psi_1^{13}(1 + t^1) + \psi_2^{23} + \psi_3^{13} t^2 + \psi_3^{23} t^3.
\]

Because \( [d^1, d^1] = 0 \), the universal infinitesimal deformation is miniversal, and there are no relations on the base \( A = \mathbb{C}[[t', t^2]] \). Along the curve \( t^2 = t' = 0 \), we have \( g^*(d^\infty) = d(1 : 1) \) where \( g \) is determined by the matrix

\[
G = \begin{bmatrix} t^3 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}.
\]
This means that there is a jump deformation from $d_2$ to $d(1 : 1)$. Otherwise, we have that $d^\infty \sim d(\alpha : \beta)$ where

$$\alpha, \beta = \frac{2 + t^1 \pm \sqrt{(t^1)^2 - 4t^2t^3}}{2},$$

as long as $t^t \neq -2$. Thus we see that locally (for small values of the parameters $t$) $d_2$ deforms into elements of the family $d(\lambda : \mu)$ which are "near" to $d(1 : 1)$. Thus $d_2$ deforms as if it were the element $d(1 : 1)$, but is distinguishable from it in terms of deformation behaviour because it has a jump deformation, and in addition, it has a larger parameter space of deformations. Note that the smooth deformations of $d_2$ along the family factor through the jump deformation from $d_2$ to $d(1 : 1)$, and therefore $d_2$ does not belong to the stratum given by the family $d(\lambda : \mu)$.

5.6. The codifferential $d^\dagger$. We have

$$H^1 = (\varphi_3^2, \varphi_2^3, \varphi_1^1 + \varphi_2^2, \varphi_2^2 - \varphi_3^3),$$

$$H^2 = (\psi_1^{12}, \psi_2^{12}, \psi_1^{13}, \psi_2^{13}, \psi_3^{13} - \psi_2^{13}),$$

$$H^3 = (\psi_2^{13}, \psi_3^{13}).$$

The universal infinitesimal deformation is

$$d^1 = \psi_1^{23} + \psi_1^{12}t^1 + \psi_2^{12}t^2 + \psi_3^{13}t^3 + \psi_2^{13}t^4 + (\psi_3^{13} - \psi_2^{13})t^5.$$

In this case, the miniversal deformation $d^\infty$ is equal to the infinitesimal deformation, and we compute

$$[d^\infty, d^\infty] = 2\varphi_3^{123}(t^1t^4 + t^3t^5) + 2\varphi_3^{123}(t^1t^5 - t^2t^3),$$

which means that there are two relations on the base $\mathcal{A}$ of the versal deformation. We have $\mathcal{A} = \mathbb{C}[t^1, t^2, t^3, t^4, t^5]=(t^1t^4 + t^2t^5, t^1t^5 - t^2t^3)$. The matrix of the versal deformation is

$$A = \begin{bmatrix} t^1 & t^2 & t^3 & 1 \\ -t^5 & t^4 & 0 & 0 \\ t^2 & t^5 & 0 & 0 \end{bmatrix}.$$

However, due to the relations, not every such $\mathcal{A}$ is actually the matrix of a 3-dimensional Lie algebra. We have to solve the relations and then consider the resulting matrices, in order to classify the deformations. It is easy to obtain the solutions using Maple. We have three solutions, given by

1. $t^1 = t^5 = 0$,
2. $t^3 = t^4 = t^5 = 0$,
3. $t^5 = -t^1t^4/\delta^2, t^2 = -t^1t^4/\delta^2$.

Thus the solutions give rise to a 2-dimensional and two 3-dimensional pieces.

For the first solution, along the surface $t^1t^4 + (t^5)^2 = 0$, we have $d^\infty \sim d(1 : -1)$, and otherwise $d^\infty \sim d$, which means that there is a three parameter family of jump deformations to $d_1$ and a two parameter family of jump deformations to $d(1 : -1)$.

For the second solution, along the curve $t^1 = \alpha + \beta, t^5 = \alpha\beta$, we have $d^\infty \sim d(\alpha : \beta)$, which means that there is a jump deformation from $d^\infty$ to $d(\alpha : \beta)$ for every value of $(\alpha : \beta)$.

For the third solution, along the surface $t^5 = \alpha + \beta, t^1 = -\alpha\beta$, we have $d^\infty \sim d(\alpha : \beta)$, which again gives a family of jump deformations.

As a consequence, we see that there are jump deformations from $d_1$ to every codifferential in the moduli space except $d_2$. We also see that although the tangent space is 5-dimensional at the point $d_1$, deformations of this codifferential actually live along lower dimensional varieties, which illustrates a common situation in a moduli space of Lie algebras.

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Figure 1. The Moduli Space of 3-dimensional Lie Algebras. The spiral arrows represent jump deformations between elements of different strata. The sphere represents the 1-dimensional family, which is actually a stratum given by the orbifold $\mathbb{P}^1/\Sigma_3$. The special points $d_1$, $d_2$ and $d_3$ each form a 0-dimensional stratum.

6. Conclusions

The moduli space of 3-dimensional Lie algebras has a natural stratification by orbifolds, three of which are just points, with the remaining piece given by $\mathbb{P}^1/\Sigma_3$. The maps between these pieces are given by jump deformations. In the case of $d_1$, there are jump deformations to all the points in the $\mathbb{P}^1/\Sigma_3$ stratum. The orbifold points play a special role in the moduli space, either because they have extra deformations, or because there are extra deformations to them. We illustrate the moduli space of three-dimensional Lie algebras in Figure 1 above.

In [7], the moduli space of 4-dimensional Lie algebras was studied. Although that picture is more complex, the main features, such as the stratification by orbifolds, with jump deformations connecting the strata, already occur in the three-dimensional picture.

References

Eigenfunction Expansion Approach to the Rapid
Numerical Evaluation of Hilbert Transforms

by
Corey D. Schuster, Department of Chemistry
Faculty Mentor: Dr. Frederick W. King

1. Introduction
Hilbert transforms occur widely in a variety of problems in science and engineering [1-2]. As a consequence in part, the numerical evaluation of Hilbert transforms has been studied intensely using a number of different approaches. The Hilbert transform of a function \( f \) denoted \( Hf \) is defined by

\[
(Hf)(x) = \frac{1}{\pi} \lim_{\epsilon \to 0^+} \left( \int_{-\infty}^{-x+\epsilon} \frac{f(s)ds}{x-s} + \int_{x-\epsilon}^{\infty} \frac{f(s)ds}{x-s} \right)
\]

(1)

In equation (1) \( P \) designates the Cauchy principal value, which can be expressed by

\[
(Hf)(x) = \frac{1}{\pi} \lim_{\epsilon \to 0^+} \left( \int_{-\infty}^{-x+\epsilon} \frac{f(s)ds}{x-s} + \int_{x-\epsilon}^{\infty} \frac{f(s)ds}{x-s} \right)
\]

(2)

We note that the Hilbert transform is also defined using the opposite sign convention to that given in equation (1). From equation (1) we see that the Hilbert transform is a linear operator, that is, for functions \( f \) and \( g \) and constants \( \alpha \) and \( \beta \), \( H(\alpha f + \beta g) = \alpha (Hf) + \beta (Hg) \). We will make use of the linearity of the Hilbert transform operator in later sections. For a function \( f \) satisfying \( f \in L^p(\mathbb{R}) \) with \( 1 < p < 1 \), where \( L^p(\mathbb{R}) \) denotes the class of Lebesgue integrable functions on the real line \((-1,1)\), then the Hilbert transform of \( f \) satisfies \( Hf \in L^p(\mathbb{R}) \). The most important practical case of interest is for functions that satisfy \( f \in L^1(\mathbb{R}) \). A comment on notation is appropriate: \( (Hf)(x) \) indicates the Hilbert transform of \( f \) and \( t \) is the dummy integration variable, and this is evaluated at the point \( x \). This will be written more concisely as \( (Hf)(x) \) when there is no need to specify the integration variable; however, if there is no risk of confusion we will write \( H[f(x)] \) for the Hilbert transform.

There is continuing interest in the development of numerical methods to obtain a precise evaluation of Hilbert transforms and other related singular integrals [5-6]. Some strategies have focused on avoiding the principal value integrals altogether. Weideman [7] studied the numerical evaluation of the Hilbert transform using an eigenfunction expansion technique. The eigenfunctions of the Hilbert transform operator can be written as

\[
\Phi_n(x) = \frac{(1+ix)^n}{(1-ix)^{n+1}} \text{ for } n \in \mathbb{Z},
\]

(3)

with

\[
H\Phi_n = -i \text{ sign}(n) \Phi_n \text{, for } |n| \geq 1,
\]

(4)

and

\[
H\Phi_0 = -i \Phi_0.
\]

(5)

The standard definition of the signum function makes either no assignment for \( \text{sign}(0) \), or is sometimes assigned the value 0. It will be useful to introduce the sign function defined by

\[
\text{sign}(n) = \begin{cases} 
1 & \text{for } n \geq 0; \\
-1 & \text{for } n < 0.
\end{cases}
\]

(6)
The functions $\Phi_n(x)$ form an orthogonal basis for $L^2(\mathbb{R})[8]$. Weidman takes the function of interest and expands it as

$$f(x) = \sum_{n=-\infty}^{\infty} a_n \Phi_n(x),$$

(7)

where $a_n$ are expansion coefficients, determined from the formula

$$a_n = \frac{1}{\pi} \int_{-\infty}^{\infty} \Phi^*_n(x)f(x)dx.$$  

(8)

From this result it follows that

$$(Hf)(x) = \sum_{n=-\infty}^{\infty} a_n H \Phi_n(x) = -i \sum_{n=-\infty}^{\infty} a_n \text{sgn}(n) \Phi_n(x).$$

(9)

Weidman examines several examples, and determines the form of the coefficients $a_n$. For the case $f(x) = \frac{1}{1 + x^2}$

the results are exact, since the function can be expanded in a compact closed form in terms of the eigenfunctions in equation (3). For functions that decay in a significantly different manner from this example, the eigenfunction decomposition approach of Weidman yields more slowly converging expansions.

2. Theory

In this work we take up a variant of the Weidman scheme. Our focus is on rapidly decaying functions, which arise in several important areas [1-2]. Two different methods are presented for the numerical evaluation of the Hilbert transform.

2.1 Fourier transform approach

In the first approach considered, the Hilbert transform is given terms of an expansion of Hermite functions. We start by expanding the function of interest as

$$f(x) = \sum_{n=0}^{\infty} a_n u_n(x),$$

(11)

where $u_n(x)$ is given by

$$u_n(x) = \frac{H_n(x)e^{-x^2}}{\sqrt{2^n n! \sqrt{\pi}}}.$$  

(12)

Here $H_n(x)$ is a Hermite polynomial of degree $n$. It is well known that the functions $u_n(x)$ form an orthonormal basis for $L^2(\mathbb{R})$. The $a_n$ is an expansion coefficient determined from

$$a_n = \int_{-\infty}^{\infty} f(x)u_n(x)dx.$$  

(13)

Similarly, we can express the $(\text{sgn}(x)$ Fourier transform) for the function of interest as

$$\langle \langle \text{sgn}(x) \rangle \rangle \mathcal{F}f(x) = \sum_{n=0}^{\infty} \mu_m u_m(x).$$

(14)

Where $\mu_m$ is given by

$$\mu_m = \int_{-\infty}^{\infty} \langle \langle \text{sgn}(x) \rangle \rangle \mathcal{F}f(x)u_m(x)dx,$$

(15)

and $\text{sgn} x$ denotes the signum function defined by

$$\text{sgn} x = \begin{cases} 
1 & x > 0 \\
0 & x = 0 \\
-1 & x < 0
\end{cases}$$

(16)

Often $\text{sgn}(0)$ is not assigned a value; however, to ensure that the left side of equation (14) is defined
at 0 we adopt the above definition for the signum function. By substituting equation (11) into equation (14) we get the following

\[ (\{\text{sgn}(x)f\}(x) = \text{sgn} x \sum_{n=0}^{\infty} \alpha_n(Fu_n)(x). \]  

(17)

It is well known [9] that

\[ (Fu_n)(x) = (-i)^n u_n(x), \]  

(18)

and

\[ (F^{-1}u_n)(x) = i^n u_n(x). \]  

(19)

Using this relationship we can simplify equation (17) to

\[ (\{\text{sgn}(x)f\}(x) = -\text{sgn} x \sum_{n=0}^{\infty} \alpha_n(-i)^n u_n(x). \]  

(20)

By substituting equation (20) into equation (15) we can obtain the following expression

\[ \mu_m = -\sum_{n=0}^{\infty} \alpha_n(-i)^n \int_{-\infty}^{\infty} u_m(x) \text{sgn} x u_n(x) dx. \]  

(21)

The integral in equation (21) can be expressed as the sum of two integrals by taking advantage of the signum function and the appropriate change of variable. This leads to the following compact expression

\[ \mu_m = -\sum_{n=0}^{\infty} \alpha_n(-i)^n [1 - (-1)^{n+m}] \int_{0}^{\infty} u_m(x) u_n(x) dx. \]  

(22)

Clearly, whenever \( n + m \) is even, \( \mu_m \) is 0. Therefore \( n + m \) must be odd in order to contribute to the sum. If we set \( m \) to be even, then \( n \) must be odd and vice versa. We let \( m = 2k \) and \( n = 2j + 1 \), where \( k, j \in \mathbb{Z}^* \) to attain

\[ \mu_{2k} = -i \sum_{j=0}^{\infty} \alpha_{2j+1}(-1)^j I_{k,j}, \]  

(23)

and let \( m = 2k + 1 \) and \( n = 2j \) where \( k, j \in \mathbb{Z}^* \) to attain

\[ \mu_{2k+1} = \sum_{j=0}^{\infty} \alpha_{2j}(-1)^j I_{k,j}. \]  

(24)

In equations (23) and (24) \( I_{k,j} \) is defined as

\[ I_{k,j} = 2 \int_{0}^{\infty} u_{2k}(x) u_{2j+1}(x) dx. \]  

(25)

Using a key connection between Fourier and Hilbert transforms [3,4]

\[ (FHf)(x) = -i\text{sgn}(x)(Ff)(x)|x|, \]  

(26)

we can apply equation (14) to the Hilbert transform as follows

\[ (Hf)(x) = -i \left\{ F^{-1} \left\{ \sum_{m=0}^{\infty} \mu_m u_m(x) \right\} \right\}(x) = -i \sum_{m=0}^{\infty} \mu_m u_m(x). \]  

(27)

Rewriting equation (27) to account for the even and odd contributions of \( m \) and substituting equations (23) and (24) we have

\[ (Hf)(x) = \sum_{k=0}^{\infty} (-1)^k u_{2k}(x) \sum_{j=0}^{\infty} (-1)^j \alpha_{2j+1} I_{k,j} + \sum_{k=0}^{\infty} (-1)^k u_{2k+1}(x) \sum_{j=0}^{\infty} (-1)^j \alpha_{2j} I_{k,j}. \]  

(28)

To evaluate the \( I_{k,j} \) integral we begin by expressing \( I_{k,j} \) in terms of Hermite polynomials, and using a relationship between Hermite polynomials and associated Laguerre polynomials with the appropriate change of variable yields the following expression

\[ I_{k,j} = \frac{(-1)^{k+j} (k+j+1)! t^j}{\sqrt{(2k)!} (2j+1)!} \int_{0}^{\infty} L_{k}^{(1/2)}(t) L_j^{(1/2)}(t) e^{-t} dt. \]  

(29)
\[ I_{k,j} = \frac{(-1)^{k+j}2^{k+j+\frac{3}{2}}k!j!\Gamma(k + \frac{1}{2})\Gamma(j + \frac{3}{2})^2}{\pi^2(2k+1)(2j+1)\Gamma(2k+1)\Gamma(2+2j)} \]  

(30)

The gamma functions can be simplified further to give a final expression for \( I_{k,j} \)

\[ I_{k,j} = \frac{(-1)^{k+j}2^{k+j+\frac{3}{4}}k!j!\Gamma(2k+1))}{\pi(2j+1)\sqrt{\pi}} \]  

(31)

It is well known that the Hilbert transform of an even function is an odd function and vice versa, this allows a simplification in the evaluation of equation (28), that is, only one of the double sums will be non-zero. Also, for functions in which \( \alpha_j \) is a finite set of terms, its summation will also be finite.

2.2 Direct series expansion approach

The second numerical approach involves applying the Hilbert transform directly to equation (11) to get the following

\[ (Hf)(x) = \sum_{n=0}^{\infty} a_n H[u_n(x)]. \]  

(32)

This can be simplified by expanding \( u_y(x) \) as a finite sum [10] to get

\[ (Hf)(x) = \sum_{n=0}^{\infty} c_n \frac{\sqrt{(2n+1)^2}2^{n+1}}{\pi} \sum_{m=0}^{\infty} \frac{(-1)^{n+m} H[2(n-m)e^{i\pi/4}]}{4nm(2n-2m)!} \]

\[ + \sum_{n=0}^{\infty} c_{2n+1} \frac{\sqrt{(2n+1)^2}2^{n+1}}{\pi} \sum_{m=0}^{\infty} \frac{(-1)^{n+m} H[2(n-m)+1e^{i\pi/4}]}{4nm(2n-2m+1)!} \]  

(33)

where \( H[2(n-m)e^{i\pi/4}] \) and \( H[2(n-m)+1e^{i\pi/4}] \) are known analytically [11]. One of the strengths of this method is that if the function of interest can be expanded in a finite series from equation (11) the Hilbert transform can be computed to high accuracy. Also, one infinite series is encountered for a general function of interest not taking into account the evaluation of \( H[2ne^{i\pi/4}] \), whereas in the Fourier transform approach two infinite series will be encountered in many cases.

<table>
<thead>
<tr>
<th>Case</th>
<th>( f(x) )</th>
<th>( (Hf)(x) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( e^{-ax^2} a &gt; 0 )</td>
<td>(-ie^{-ax^2} \text{erf}(i\sqrt{ax}))</td>
</tr>
<tr>
<td>2</td>
<td>( xe^{-ax^2} a &gt; 0 )</td>
<td>( \pi G(a,x) - \frac{1}{\sqrt{ax}} )</td>
</tr>
<tr>
<td>3</td>
<td>( x^2e^{-ax^2} a &gt; 0 )</td>
<td>( x^2 G(a,x) - \frac{1}{\sqrt[3]{ax}} )</td>
</tr>
<tr>
<td>4</td>
<td>( \cos(bx)e^{-ax^2} a, b &gt; 0 )</td>
<td>( e^{-ax^2} j_m(e^{b\sqrt{a}}e^{</td>
</tr>
<tr>
<td>5</td>
<td>( e^{-</td>
<td>x</td>
</tr>
<tr>
<td>6</td>
<td>( \frac{1}{1+x^2} )</td>
<td>( \frac{x}{1+x^2} )</td>
</tr>
</tbody>
</table>

Table 1: Hilbert Transforms.
3. Computational approach

For the numerical evaluation of the Hilbert transform we chose several test functions found in Table 1 for which the exact Hilbert transform is well known. The test functions were chosen by their rate of decay away from the origin.

For notational compactness \( G(a, x) \) is the Hilbert transform \( H[e^{-ax^2}] \), and the exponential integral functions are defined by

\[
E_i(z) = - \pi \int_{-\infty}^{\infty} e^{-t} dt / t,
\]

and

\[
E_1(z) = \int_{1}^{\infty} e^{-t} dt / t.
\]

In Table 1 \( \Im \) denotes the imaginary part and \( \text{erf}(z) \) is the error function defined by

\[
\text{erf}(z) = \frac{2}{\sqrt{\pi}} \int_{0}^{z} e^{-t^2} dt.
\]

For the test functions in Table 1 the corresponding expansion coefficients from equation (11) are tabulated in Table 2.

<table>
<thead>
<tr>
<th>( f(x) )</th>
<th>Expansion coefficients ( a_{2n} ) and ( a_{2n+1} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 2^{2m}e^{-\frac{4x^2}{\pi}} )</td>
<td>( a_{2n} = \left{ \begin{array}{ll} \frac{(2m)!\pi^\frac{1}{2}}{2^{2m-n}(m-n)!\sqrt{(2n)!}} &amp; n \leq m \ 0 &amp; n &gt; m. \end{array} \right. )</td>
</tr>
<tr>
<td>( 2^{2m+1}e^{-\frac{4x^2}{\pi}} )</td>
<td>( a_{2n+1} = \left{ \begin{array}{ll} \frac{(2m+1)!\pi^\frac{1}{2}}{2^{2m-n+1}(m-n)!\sqrt{(2n+1)!}} &amp; n \leq m \ 0 &amp; n &gt; m. \end{array} \right. )</td>
</tr>
<tr>
<td>( 2^{2m}e^{-ax^2} ) ( a &gt; 0 )</td>
<td>( a_{2n} = \sqrt{(2n)!}\sqrt{\pi} \sum_{j=0}^{n} \frac{(-1)^{j}(2n-2j+2m)!\sqrt{(a+\frac{j}{2})}}{j!(n-j+m)!(2n-2j)!} )</td>
</tr>
<tr>
<td>( 2^{2m+1}e^{-ax^2} ) ( a &gt; 0 )</td>
<td>( a_{2n+1} = \sqrt{(2n+1)!}\sqrt{\pi} \sum_{j=0}^{n} \frac{(-1)^{j}(2n-2j+2m+2)!\sqrt{(a+\frac{j}{2})}}{j!(n-j+m+1)!(2n-2j+1)!} )</td>
</tr>
<tr>
<td>( \cos(bz)e^{-ax^2} ) ( a &gt; 0, b \geq 0 )</td>
<td>( a_{2n} = \sqrt{(2n)!}\sqrt{\pi} \sum_{j=0}^{n} \frac{(-1)^{j}(a+\frac{j}{2})F_1(\frac{1}{2}-j+n;\frac{1}{2}; \frac{-z^2}{2(a+2b)})}{j!(n-j)!} )</td>
</tr>
<tr>
<td>( e^{-ax} ) ( a &gt; 0 )</td>
<td>( a_{2n} = \frac{2^{2n+1}(2n)!}{\pi^\frac{1}{2}} \sum_{j=0}^{n} \frac{(-1)^{j}((2n-2j)!\sqrt{(2n-2j+1)!})F_1(\frac{1}{2}-j+n+\frac{1}{2}; \frac{1}{2}; \frac{-z^2}{2})}{j!(n-j+1)!(2n+2j)!} )</td>
</tr>
<tr>
<td>( \frac{1}{1+x^2} )</td>
<td>( a_{2n} = \frac{(2n)!\sqrt{\pi}}{2^n} \sum_{j=0}^{n} \frac{(-1)^{j}!(j-n+\frac{1}{2}; \frac{1}{2})}{j!(n-j)!} )</td>
</tr>
</tbody>
</table>

Table 2: Expansion coefficients used for the test functions.

Here, \( \Gamma(a, z) \) denotes the incomplete gamma function, and \( F_1(a; b; z) \) designates the Kummer confluent hypergeometric function. We demonstrate the numerical method by first con-
Considering this simple example

\[ f(x) = x^{2m}e^{-\frac{x^2}{2}} \]  

(37)

Since the function is even we can expand it using equation (11) as follows:

\[ f(x) = \sum_{n=0}^{m} \alpha_n u_{2n}(x), \]  

(38)

and for a particular test case consider \( m = 1 \), then the expansion coefficients from Table 2 are

\[ \alpha_0 = \frac{\pi^{\frac{1}{4}}}{2}, \alpha_2 = \frac{\pi^{\frac{1}{4}}}{\sqrt{2}}, \alpha_{2n} = 0 \text{ for } n \geq 2. \]  

(39)

Thus equation (28) can be simplified to

\[ (Hf)(x) = \sum_{k=0}^{\infty} (-1)^{k} u_{2k+1}(x) \sum_{j=0}^{m} (-1)^{j} \alpha_{2j} I_{j,k} \]  

(40)

For another similar example consider

\[ f(x) = x^{2m+1}e^{-\frac{x^2}{2}} \]  

(41)

Analogously, the expansion coefficients can be found from Table 2 and equation (28) can be simplified to

\[ (Hf)(x) = -\sum_{k=0}^{\infty} (-1)^{k} u_{2k}(x) \sum_{j=0}^{m} (-1)^{j} \alpha_{2j+1} I_{k,j} \]  

(42)

Thus, for the two examples above, since the functions can be written as a finite series in equation (11), the resulting Hilbert transform will contain a single infinite series versus two infinite series for a general function that cannot be expanded in a finite series from equation (11). A slightly more generalized example is the following function where \( a \neq 1/2 \)

\[ f(x) = x^{2m}e^{-ax^2}. \]  

(43)

The expansion coefficients for this function can be found in Table 1. The resulting Hilbert transform now involves two infinite series as mentioned previously. It should be noted that rescaling of the expansion variable will lead to a finite series expansion. An alternative and computationally more appealing approach is to note that with the appropriate change of variable we have the following,

\[ (Hf)(x) = \left( \frac{1}{2a} \right)^{m} H \left[ e^{k \cdot \frac{1}{2}}e^{-\frac{x^2}{2}} \right](x\sqrt{2a}). \]  

(44)

The approach of the preceding result allows the Hilbert transform to be obtained as in (40).

For all these cases the Hilbert transform can be found in terms of a single infinite series which will allow us to directly apply the different convergence accelerators. For the moment we will consider a general case of functions where a finite series for equation (11) cannot be obtained, resulting in a double infinite series. To apply a convergence accelerator to the general case we make use of an interchange of order of summation [12] on equation (28) transforming the double infinite series to a combination of a finite and an infinite series as shown below

\[ (Hf)(x) = -\sum_{k=0}^{\infty} (-1)^{k} \sum_{j=0}^{m} \alpha_{2j+1} I_{k-j} u_{2(k+j)}(x) \]  

\[ + \sum_{k=0}^{\infty} (-1)^{k} \sum_{j=0}^{m} \alpha_{2j} I_{k,j} u_{2(k+j)+1}(x). \]  

(45)

Among the convergence accelerators employed were the Levin-u [13], Levin-t' [14, 15], Weniger (1) [15], Weniger (2) [15], and the Wynn \( \varepsilon \)-algorithm [16, 17]. These convergence accelerators are given by the following formulas. The Levin-u formula is
The Levin-$r'$ formula is
\[ u_k = \sum_{j=0}^{k} c_j (j+1)^{k-2} \frac{S_j + 1}{A_{j+1}}, \]
\[ t_k^{(r')} = \frac{1}{k} \sum_{j=0}^{k} c_j (j+1)^{k-1} \frac{1}{A_{j+1}}. \] (46)

the Weniger (1) formula is
\[ w_k^{(1)} = \sum_{j=0}^{k} c_j (-j-1)_{k-1} \frac{S_j + 1}{A_{j+1}}, \]
\[ \sum_{j=0}^{k} c_j (-j-1)_{k-1} \frac{1}{A_{j+1}}. \] (47)

the Weniger (2) formula is
\[ w_k^{(2)} = \sum_{j=0}^{k} c_j (j+1)_{k-1} \frac{S_j + 1}{A_{j+1}}, \]
\[ \sum_{j=0}^{k} c_j (j+1)_{k-1} \frac{1}{A_{j+1}}. \] (48)

and the Wynn $\varepsilon$-algorithm is
\[ \varepsilon_k^{(n)} = \varepsilon_k^{(n+1)} + \frac{1}{\varepsilon_k^{(n+1)} - \varepsilon_k^{(n)}}, \] (49)

with
\[ \varepsilon_0^{(n)} = 0, \varepsilon_0^{(n)} = S_n, \] (50)

where $S_j$ is the $j$-th partial sum of the series, $A_j$ is the $j$-th term of the series and $c_j = (-1)^j$, where $\binom{k}{j}$ is a binomial coefficient.

For computational efficiency the Wynn $\varepsilon$-algorithm was computed using the following property [16]
\[ \varepsilon_{2k}^{(n)} = \frac{H_n^{(k+1)}(\Delta^2 s)}{H_n^{(k)}(\Delta^2 s)}, \] (51)

where $H_n^{(\theta)}(s)$ is a Hankel determinant given by
\[ H_n^{(k)}(s) = \begin{bmatrix} s_n & \cdots & s_{n+k-1} \\ \vdots & \ddots & \vdots \\ s_{n+k-1} & \cdots & s_n + 2k - 2 \end{bmatrix}, \quad n \geq 0, \ k \geq 1 \] (52)

$s_n$ is the $n$th partial sum of the sequence $s$, and $\Delta$ is the forward difference operator.

4. Results and Discussion
Using the exact formula from Table 2 we were able to test the precision of the numerical evaluations using the different numerical techniques. In Table 3 we show a comparison of the numerical and exact evaluations of the Hilbert transform for the test functions.

The test functions 1-4 gave the best results offering 15 significant digits as a worse case scenario for $x = 7$ and as good as 24 significant digits for case 1 at $x = 1/4$. These four test functions exhibited a gaussian behavior similar to the Hermite function $u_n(x)$; thus, their expansion coefficients from equation (13) are going to converge rapidly. The test function 5 and 6, however, gave results ranging from 2-6 significant digits. While these two functions decay away from the origin,
they do not do so in a Gaussian manner. Thus, their behavior is not similar to the \( \text{un}(x) \) and their expansion coefficients as a result converge more slowly. By examining either equation (45) or (33) we see that the only difference between the numerical Hilbert transform of two different functions is the expansion coefficient associated with that function. This indicates a direct correlation between the behavior of the expansion coefficient and the behavior of the Hilbert transform, in particular, the faster the expansion coefficient converges, the faster the Hilbert transform will converge.

For all the test functions, the best results were attained using the Wynn \( \varepsilon \)-algorithm. By analyzing the individual terms of equation (45) for case 4 with \( x = 1 \), the sequence behaved in a slowly convergent manner with irregular signs (see Figure 1) which would be somewhat similar to the terms taken by \( \sin (kx)/k \). For this situation, Wynn's \( \varepsilon \)-algorithm was the most suitable choice for convergence acceleration [18].

<table>
<thead>
<tr>
<th>Case</th>
<th>( x_0 )</th>
<th>( (HF)(x_0) ) (exact result)</th>
<th>( (HF)(x_0) ) (numerical result)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>0.292005133867174646471635</td>
<td>0.292005133867174646471651</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
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<tr>
<td>1/4</td>
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<td>1/4</td>
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<td>-0.111149412760337542370149</td>
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</tr>
<tr>
<td>1/4</td>
<td>0.03221672330837706</td>
<td>0.03221672330837708</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>0.3370871404666270460661</td>
<td>0.3370871404666270460660</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>0.559773149189766017818</td>
<td>0.559773149189766017821</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>0.062416237155745895</td>
<td>0.062416237155745869</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>0.3156</td>
<td>0.3183</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>0.4027</td>
<td>0.4035</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>0.0798005011</td>
<td>0.0798005051</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>0.2352941</td>
<td>0.2352956</td>
<td></td>
</tr>
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<td>1/4</td>
<td>0.5000000</td>
<td>0.5000070</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>0.14000</td>
<td>0.14012</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3.** A comparison of numerical values for the Hilbert transform versus the exact evaluation for the test functions. The values \( a = 12/11 \) and \( b = 11/13 \) have been employed.

**Figure 1:** Plot of individual terms of the Hilbert transform from equation (45) for case 4 with \( x = 1 \).

The Levin and Weniger convergence accelerators offered much less precise results compared to the Wynn \( \varepsilon \)-algorithm, however, based on the form of the series this is not surprising [18] since the series was non-monotonic and non-alternating. Table 4 shows a comparison of the convergence accelerators employed.

The function in Table 4 was chosen because all the test functions exhibited similar trends.
in precision with the convergence accelerators.

From Table 3 we can see that the numerical method works well for functions demonstrating a gaussian behavior. By examining the expansion coefficients in Figure 2 for the test functions we indeed see a trend in their convergence rates as mentioned previously.

For the sake of readability only the expansion coefficients for case 4 is shown because their convergence is similar to cases 1-3 with case 4 showing just slightly slower convergence. From Figure 2 we do see that the convergence of case 4 is much faster than that of case 5 and 6. This indicates that the convergence of the Hilbert transform in equations (45) and (33) are directly related to the convergence of the expansion coefficients. The numerical method proposed by Weideman also showed that a slower convergence rate for the expansion coefficients resulted in a slower converging Hilbert transform.

<table>
<thead>
<tr>
<th>Method</th>
<th>$(Hf)(1)$</th>
<th>$(Hf)(1/4)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levin-u</td>
<td>0.559796</td>
<td>0.337064</td>
</tr>
<tr>
<td>Levin-t'</td>
<td>0.559756</td>
<td>0.337073</td>
</tr>
<tr>
<td>Wengier(1)</td>
<td>0.5597735</td>
<td>0.3370865</td>
</tr>
<tr>
<td>Wengier(2)</td>
<td>0.55969</td>
<td>0.337033</td>
</tr>
<tr>
<td>Wynn ε</td>
<td>0.559773149180786017821</td>
<td>0.3370871404860270460659</td>
</tr>
<tr>
<td>Exact</td>
<td>0.559773149180786017818</td>
<td>0.3370871404860270460661</td>
</tr>
</tbody>
</table>

Table 4: A comparison of the different convergence accelerator methods for $f(x) = \cos (bx)e^{-ax^2}$.
The values $a = 12/11$ and $b = 11/13$ have been employed.

![Figure 2: Comparison of the expansion coefficients for cases 4, 5, and 6.](image)

The Fourier transform method offered a few more digits of precision over the direct series method for $x=1/4$. However, for the Fourier method the results were obtained by setting $n=30$ and $k=15$ for all calculations in equation (52) while for the direct method the results were obtained by setting $n=12$ and $k=12$ for all calculations in equation (52). For $x=1$ both methods performed equally well and for $x=7$ the direct method offered a few more digits of precision over the Fourier.

Attempts at improving the precision for cases 5 and 6 involved brute force summation of the first several terms of the Hilbert transform that were erratic and then applying the convergence accelerators to the remaining series and combining the results. This was tried on both cases with all the convergence accelerators and did not produce any increase in precision over the convergence 13 accelerator on the original series. Also, attempts were made to split the series by even and odd contributions of equation (45). From Figure 1 we see that splitting the series that way would produce two sequences that are slowly convergent and non-alternating with an irregular sign pattern. The convergence accelerators were applied to both of the resulting series and their results were combined. This also offered no increase in precision for the two functions.
Another method that could offer better precision would be to change the expansion function from equation (11). By changing the orthogonal function $u_n(x)$ to a different orthogonal function whose weight function behaves more similar to the function of interest, the resulting expansion coefficients would converge faster causing the Hilbert transform to converge faster. This method would only be compatible with the direct series approach because the Fourier series approach relies on the function un(x) being an eigenfunction of the Fourier transform.

5. Conclusion
In summary, two methods have been presented for the numerical evaluation of the Hilbert transform in which computationally efficient and precise values were attained for a number of the test functions. This approach is particularly effective for functions exhibiting a gaussian behavior. For the gaussian functions, precise values between 15-24 significant figures were collected and for "non-gaussian" functions, values between 2-6 significant figures were collected. Several convergence accelerator techniques were employed for the slowly convergent series encountered in the Hilbert transform, with the Wynn ε-algorithm providing the best precision.

Acknowledgments
Support from the National Science Foundation and from Donors of the Petroleum Research Fund, administered by the American Chemistry Society, are greatly appreciated. We also thank the Ronald E. McNair Postbaccalaureate Achievement Program and the Office of University Research, University of Wisconsin-Eau Claire for support, and the Spanish Ministerio de Educacion (PR2003-0227), which provided financial assistance for the visit of I. Porras.

References
Quantum Mechanical Characterization of Nitrile-Borane Complexes: RCN-BH$_3$

by

Elizabeth L. Smith, Department of Chemistry
Faculty Mentor: Dr. James A. Phillips

Introduction

Lewis acid-base complexes have been the subject of numerous studies over the past several decades. Much of the recent interest has stemmed from the observations of peculiar structural properties among nitrile-BF$_3$ systems$^{1,6}$. For example, the gas phase structure for acetonitrile-boron trifluoride (CH$_3$CN-BF$_3$) has a B-N distance of 2.01 Å, which is intermediate between that of van der Waals and chemical interaction. Furthermore, the gas phase structure differs markedly from that of the crystalline solid, which has a B-N distance of 1.63 Å, 0.4 Å shorter than the gas phase. Citing IR frequency shifts, Wells and Phillips$^7$ found that even inert argon matrices altered the structure of CH$_3$CN-BF$_3$. Subsequent studies found that this effect varied across various matrix media, largely in accord with the dielectric stabilization provided by these environments. In a computation study, Giesen and Phillips$^8$ revealed that the complex has a flat, anharmonic bond potential, which seemed to underlie this medium sensitivity.

These medium effects are even more pronounced for complexes with weaker nitrile donors. For HCN-BF$_3$, the gas phase structure has a B-N distance of 2.473 Å, and an NBF angle of 91.5°. In the solid state, however, the bond distance is 1.638 Å with a NBF angle of 105.6°. Using B3PW91/aug-cc-pVTZ, the structure of HCN-BF$_3$ has a B-N distance of 2.465 Å, and a NBF angle of 93.5°, which illustrates that DFT can predict structural properties of these systems$^4$. Just recently, using B3PW91/aug-cc-pVTZ, together with crystallographic results, large gas-solid structure differences for X-CH$_3$CN-BF$_3$ were predicted.$^5$

We now turn to analogous complexes of borane to see if they exhibit similar behavior. Previous work with borane-nitrile complexes has been concerned with the CH$_3$CN-BH$_3$ complex. Experimental data on this complex is limited to vibrational spectra, as Watari$^7$ prepared a solid sample and performed a vibrational analysis. Vijay, et al.$^8$ conducted a computational study of the structure, vibrational spectra, and binding energy of CH$_3$CN-BH$_3$ using MP2/DZP. The B-N bond distance was 1.596 Å, quite short for a B-N dative bond, but the binding energy for the complex was only -12.921 kcal/mol. Both indicate a strong interaction between the two monomers.

This study focuses on nitrile-borane complexes, with the intent of gauging the extent to which these systems exhibit medium-dependent structural changes, similar to those observed for nitrile-borane trifluoride complexes. We have steered our efforts toward weaker nitrile donors, more so than CH$_3$CN, which should tend towards longer B-N distances in the gas phase, and thus be more prone to structural changes due to increased bonding in condensed phases. Gas phase structures and frequencies were calculated for borane, several nitrile donors, and the complexes formed from them. These donors include HCN, CH$_3$CN, FCH$_2$CN, and F$_2$CCN. Calculations were performed using density functional theory (B3LYP, B3PW91, MPW1PW91, B98, and B97-2) and MP2 methods with aug-cc-pVTZ as a basis set. HCN-BH$_3$ was examined in further detail, as we conducted higher-level geometry calculations with MP4 and CCSD(T), assessed effects of dielectric
media on the equilibrium structure using PCM, and mapped the B-N distance potential with B97-2 and MP2.

Computational Methods
MP2 and DFT calculations were performed using Gaussian03 version d01. For optimizations, all geometries were constrained to \( C_{3v} \) symmetry, and convergence criteria were set using the “opt-tight” option, which sets the maximum and RMS forces to \( 1.5 \times 10^{-5} \) and \( 1.0 \times 10^{-5} \) hartree/bohr, respectively, and the maximum and RMS displacements to \( 6.0 \times 10^{-5} \) and \( 4.0 \times 10^{-5} \) bohr, respectively. An ultrafine grid was employed for all DFT calculations. The aug-cc-pVTZ basis set was used exclusively for CH\(_3\)CN, FCH\(_3\)CN, and CF\(_3\)CN. For HCN-BF\(_3\), a slightly more extended set of calculations was performed. The cc-pVTZ basis set was used in addition to aug-cc-pVTZ, in order to gauge the degree of convergence at the aug-cc-pVTZ level, and assess the effect of diffuse functions. Also, since there is a paucity of experimental structural data for these systems, we employed some higher-level methods as well, including MP4 to assess the validity of the DFT, and MP2 results for the other systems.

Results
Equilibrium Structures
Figure 1 shows the B3PW91/aug-cc-pVTZ calculated structures for CH\(_3\)CN-BH\(_3\), HCN-BH\(_3\), FCH\(_3\)CN-BH\(_3\), and CF\(_3\)CN-BH\(_3\). The results reported are for the eclipsed form of CH\(_3\)CN-BH\(_3\), FCH\(_3\)CN-BH\(_3\), and CF\(_3\)CN-BH\(_3\). A slight preference exists for the B3PW91 results based on previous results for HCN-BF\(_3\) (for which MP2 results were a few hundredths of an Å shorter). Nonetheless, Table 1 shows the B-N distances obtained using several other methods, and the results are very consistent though the MP2 results are systematically lower by 0.03 Å. Furthermore, all structural results for all complexes exhibit very short B-N distances, even for CF\(_3\)CN, which is expected to be a very weak donor. For comparison, we note that the B-N distances in the solid forms of analogous nitrile-BF\(_3\) systems are about 1.65 Å,\(^{1,6}\) and the measured distance in NH\(_3\)-BH\(_3\) (g) is 1.66 Å.\(^9\) Collectively, these data suggest that these complexes have strong B-N dative bonds. Previously, Gilbert\(^8\) obtained reasonable agreement between experiment and theory using MP2 and several DFT methods with the 6-311++G(d,p) basis set, though the B3LYP results were among the least reliable in that study. These methods computed a 1.65 Å B-N bond distance for NH\(_3\)-BH\(_3\).

It is interesting to note that all the nitrile complexes have shorter B-N bonds than NH\(_3\)-BH\(_3\).

![Equilibrium Structural Parameters for nitrile-borane complexes obtained via B3PW91/aug-cc-pVTZ](image-url)

Figure 1: Equilibrium Structural Parameters for nitrile-borane complexes obtained via B3PW91/aug-cc-pVTZ
Table 1: B-N distances

<table>
<thead>
<tr>
<th></th>
<th>B3LYP</th>
<th>B3PW91</th>
<th>MPW1PW91</th>
<th>B98</th>
<th>B97-2</th>
<th>MP2</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCN</td>
<td>1.544</td>
<td>1.530</td>
<td>1.532</td>
<td>1.540</td>
<td>1.542</td>
<td>1.583</td>
</tr>
<tr>
<td>CH₃CN</td>
<td>1.553</td>
<td>1.539</td>
<td>1.540</td>
<td>1.549</td>
<td>1.550</td>
<td>1.584</td>
</tr>
<tr>
<td>FCH₂CN</td>
<td>1.544</td>
<td>1.530</td>
<td>1.532</td>
<td>1.540</td>
<td>1.541</td>
<td>1.581</td>
</tr>
<tr>
<td>CF₃CN</td>
<td>1.534</td>
<td>1.520</td>
<td>1.523</td>
<td>1.532</td>
<td>1.532</td>
<td>1.576</td>
</tr>
</tbody>
</table>

* in units of Å, and computed with aug-cc-pVTZ basis set

Since HCN-BH₃ is the smallest system in this series, we extended the level of theory to further assess the validity of these results. At the MP4(SDQ)/aug-cc-pVTZ level of theory the B-N distance is 1.583 Å, which is quite consistent with the MP2/aug-cc-pVTZ results. The B3PW91/aug-cc-pVQZ level gave a B-N distance of 1.582 Å. For nitrile-BF₃ systems, structural results are very sensitive to the inclusion of diffuse functions, but for this system, this effect is non-existent. The B3PW91/cc-pVTZ level gave a B-N distance of 1.530 Å. We also examined the effects of condensed-phase media on the structure using PCM/B3PW91/aug-cc-pVTZ with e values of 2, 5, 10, 20, and 40, yielding B-N distances of 1.535 Å, 1.537 Å, 1.537 Å, 1.531 Å, and 1.537 Å, respectively. Thus, there is no compression of the B-N bond in dielectric environments as predicted, which is not surprising given the very short gas-phase B-N distance.

These nitrile-BF₃ complexes are not similar in structure to the analogous nitrile-BF₃ complexes. Table 2 compares the present results to various nitrile-BF₃ systems structural parameters. All of the BF₃ complexes have longer B-N distances and smaller N-B-X angles. Differences are most extreme with weaker donors, for which the BF₃ complexes are fairly weakly bonded. For example, CF₃CN-BF₃ B-N bond distance is 0.25 Å shorter than CH₃CN-BF₃, and the binding energy is about twice as large. Yet, HCN-BH₃ has a B-N distance almost 1 Å shorter than HCN-BF₃, and the binding energy is three times larger.

Table 2: Selected Structural Parameters* and Binding Energies* for Nitrile-BH₃ Complexes and the Analogous BF₃ Systems

<table>
<thead>
<tr>
<th></th>
<th>R_BN (Å)*</th>
<th>θ_N-B-X°</th>
<th>ΔE (kcal/mol)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCN-BH₃</td>
<td>1.530</td>
<td>105.5°</td>
<td>-19.85</td>
</tr>
<tr>
<td>HCN-BF₃</td>
<td>2.465</td>
<td>93.5°</td>
<td>-6.30</td>
</tr>
<tr>
<td>CH₃CN-BH₃</td>
<td>1.539</td>
<td>104.8°</td>
<td>-22.56</td>
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<tr>
<td>CH₃CN-BF₃</td>
<td>1.788*</td>
<td>101.9°</td>
<td>-8.70*</td>
</tr>
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<td>FCH₂CN-BH₃</td>
<td>1.530</td>
<td>105.1°</td>
<td>-23.30</td>
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<tr>
<td>FCH₂CN-BF₃</td>
<td>2.423</td>
<td>94.1°</td>
<td>-20.30</td>
</tr>
<tr>
<td>CF₃CN-BH₃</td>
<td>1.520</td>
<td>105.3°</td>
<td>-20.30</td>
</tr>
<tr>
<td>CF₃CN-BF₃</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* B3PW91/aug-cc-pVTZ
* MP2/aug-cc-pVTZ
* calculated at the B3PW91/aug-cc-pVTZ level. Experimental value is 2.01 Å
* MCG3//MP2/aug-cc-pVTZ result.

Figure 2 shows the potential energy curve for HCN-BH₃. The curve is morse-like and shows no unusual features. This set of data shows that HCN-BH₃ does not exhibit medium dependent
structural changes. Examining other nitrile-BF$_3$ complexes, the bond potentials for these systems tend to be flat and anharmonic.$^{2,4}$

![Figure 2: Potential energy of HCN-BH$_3$ versus B-N distance, calculated at the B97-2/aug-cc-pVTZ and MP2/aug-cc-pVTZ level of theory](image)

**Binding Energies**

The binding energy values for these complexes corroborate the implications of the structure results; the nitrile-borane complexes are quite strong with binding energies near 20 kcal/mol. We did not calculate the DFT binding energies due to previous work.$^{4,10}$ Also, we did not examine basis set superposition error, but we noted that the counterpoise correction to the binding energy for CH$_3$CN-BF$_3$ at the B3LYP/aug-cc-pVTZ level reduces the binding energy by about 0.2 kcal/mol. An effect of this magnitude is quite insignificant for systems with binding energies changes as large as 20 kcal/mol.

Table 3 shows the computed vibrational frequencies of BH$_3$ using several methods and the aug-cc-pVTZ basis set. In general, the DFT frequencies are systematically lower than the MP2 results. Previously, Andrews$^{11}$ observed the $v_2$ and $v_3$ bands in solid argon at 1129 cm$^{-1}$ and 2587 cm$^{-1}$, respectively. B3PW91 agrees best with Andrews’ $n_2$ result, and B3LYP agrees with $v_3$. We applied a scale factor of 0.96 to the MP2 results, which improves the agreement with the umbrella model, but makes the symmetric stretch agreement much worse. The $v_4$ frequency disagrees with Porter$^{12}$, but others have measured the $n_4$ frequency to be around 1190 cm$^{-1}$. Overall, our agreement is marginal, which is quite surprising given the level of theory, and the success that these methods had with BF$_3$ frequencies.

<table>
<thead>
<tr>
<th>Method</th>
<th>B3LYP</th>
<th>B3PW91</th>
<th>MPW1PW91</th>
<th>B98</th>
<th>B97-2</th>
<th>MP2</th>
<th>Approximate Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1160</td>
<td>1147</td>
<td>1150</td>
<td>1155</td>
<td>1151</td>
<td>1175</td>
<td></td>
<td>Umbrella ($v_2$)</td>
</tr>
<tr>
<td>1204</td>
<td>1192</td>
<td>1197</td>
<td>1203</td>
<td>1196</td>
<td>1237</td>
<td></td>
<td>asym bend ($v_3$)</td>
</tr>
<tr>
<td>2569</td>
<td>2553</td>
<td>2563</td>
<td>2562</td>
<td>2556</td>
<td>2607</td>
<td></td>
<td>sym stretch ($v_1$)</td>
</tr>
<tr>
<td>2696</td>
<td>2687</td>
<td>2698</td>
<td>2692</td>
<td>2688</td>
<td>2744</td>
<td></td>
<td>asym stretch ($v_4$)</td>
</tr>
</tbody>
</table>

*aug-cc-pVTZ with unit of cm$^{-1}$

Table 4 shows the experimental and computed frequency results for CH$_3$CN-BH$_3$. Our computed results are in fair agreement with Wataris’ experimental results (differences are roughly 10’s of wavenumbers). Overall a comparison of experimental and theory for all methods, the
B3PW91 level is best; we report these for CH₂CN-BH₃ and other nitrile-borane complexes below.

### Table 4: Vibrational Frequencies of CH₂CN-BH₃

<table>
<thead>
<tr>
<th>Experimental</th>
<th>Calculated</th>
<th>Calculated Shift</th>
<th>Intensity</th>
<th>Approximate Description</th>
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</thead>
<tbody>
<tr>
<td>926</td>
<td>904</td>
<td></td>
<td>8.6</td>
<td>BH₃ rock</td>
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<tr>
<td>984</td>
<td>1009</td>
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<td>3.5</td>
<td>C-C stretch</td>
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<tr>
<td>1032</td>
<td>1047</td>
<td></td>
<td>2.5</td>
<td>CH₃ rock</td>
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<tr>
<td>1153</td>
<td>1146</td>
<td>-1</td>
<td>80.6</td>
<td>BH₃ umbrella</td>
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<tr>
<td>1153</td>
<td>1149</td>
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<td>BH₃ asym bend</td>
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<td>1364</td>
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<td>CH₃ umbrella</td>
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<tr>
<td>1445</td>
<td>1458</td>
<td></td>
<td>11.9</td>
<td>CH₃ asym bend</td>
</tr>
<tr>
<td>2345</td>
<td>2422</td>
<td></td>
<td>0.6</td>
<td>CN stretch</td>
</tr>
<tr>
<td>2383</td>
<td>2453</td>
<td>-100</td>
<td>61.8</td>
<td>BH₃ sym stretch</td>
</tr>
<tr>
<td>2383</td>
<td>2499</td>
<td>-188</td>
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<td>BH₃ asym stretch</td>
</tr>
<tr>
<td>2920</td>
<td>3052</td>
<td></td>
<td>0.6</td>
<td>CH₃ sym stretch</td>
</tr>
<tr>
<td>2985</td>
<td>3131</td>
<td></td>
<td>0.3</td>
<td>CH₃ asym stretch</td>
</tr>
</tbody>
</table>

*Watari  
B3PW91/aug-cc-pVTZ  
° BH₃ frequency shift from monomer to complex  
° Units of km/mol  
° units of cm⁻¹

### Table 5: Vibrational Frequencies of HCN- BH₃

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Shift</th>
<th>Intensity</th>
<th>Approximate Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>896</td>
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<tr>
<td>1136</td>
<td>-11</td>
<td>42.9</td>
<td>BH₃ umbrella</td>
</tr>
<tr>
<td>1140</td>
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</tr>
<tr>
<td>2256</td>
<td></td>
<td>49.0</td>
<td>CN stretch</td>
</tr>
<tr>
<td>2454</td>
<td>-99</td>
<td>26.6</td>
<td>BH₃ sym stretch</td>
</tr>
<tr>
<td>2512</td>
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</tr>
<tr>
<td>3457</td>
<td></td>
<td>239.7</td>
<td>H-C stretch</td>
</tr>
</tbody>
</table>

* B3PW91/aug-cc-pVTZ with unit of cm⁻¹  
° BH₃ frequency shift from monomer to complex  
° Units of km/mol

Looking at the frequency shifts for all modes in all complexes, we see a minimal shift in the BH₃ umbrella mode, in spite of the pyramidalization of BH₃ in the complex. The asymmetric bend exhibits moderate shift of about 45-65 cm⁻¹. We see much larger shifts in both the BH₃ symmetric and asymmetric stretches (about 100 cm⁻¹ and 175 cm⁻¹, respectively). Thus, the BH₃ vibrational modes are, for the most part, sensitive to structural changes that occur within BH₃ as the complexes form.
Table 6: Vibrational Frequencies of FCH$_2$CN- BH$_3$

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Shift</th>
<th>Intensity</th>
<th>Approximate Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>985</td>
<td></td>
<td>5.7</td>
<td>C-C stretch</td>
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<tr>
<td>1018</td>
<td></td>
<td>0.9</td>
<td>C-F bend</td>
</tr>
<tr>
<td>1093</td>
<td></td>
<td>151.9</td>
<td>C-F stretch</td>
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<td>1130</td>
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<td>BH$_3$ asym bend</td>
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<td>1392</td>
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<td>41.3</td>
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<td>1471</td>
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</tbody>
</table>

* B3PW91/aug-cc-pVTZ with unit of cm$^{-1}$

* BH$_3$ frequency shift from monomer to complex

* Units of km/mol

Table 7: Vibrational Frequencies of CF$_2$CN- BH$_3$

<table>
<thead>
<tr>
<th>Frequency</th>
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<th>Intensity</th>
<th>Approximate Description</th>
</tr>
</thead>
<tbody>
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<td>880</td>
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<td>3.1</td>
<td>BH$_3$ rock</td>
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<td>93.4</td>
<td>BH$_3$ umbrella</td>
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<tr>
<td>1127</td>
<td>-65</td>
<td>0.1</td>
<td>BH$_3$ asym bend</td>
</tr>
<tr>
<td>1204</td>
<td></td>
<td>296</td>
<td>CF$_3$ asym stretch</td>
</tr>
<tr>
<td>1225</td>
<td></td>
<td>481.4</td>
<td>CF$_3$ sym stretch</td>
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</tr>
<tr>
<td>2516</td>
<td>-171</td>
<td>88.1</td>
<td>BH$_3$ asym bend</td>
</tr>
</tbody>
</table>

* B3PW91/aug-cc-pVTZ with unit of cm$^{-1}$

* BH$_3$ frequency shift from monomer to complex

* Units of km/mol

Turning to CH$_3$CN-BH$_3$, examination of the BH$_3$ asymmetric bend indicates that no systematic differences occur such that the experimental and computed frequencies differ due to structural differences between the gas and solid complexes (as in the nitrile-BF$_3$ systems). However, we do overestimate the BH$_3$ symmetric stretch and asymmetric stretch frequencies, suggesting that some structural changes may occur. Yet, given that the frequency results are at best marginal and that the B-N distances are quite short in the gas phase, it is very unlikely that a significant compression of the B-N bond occurs in condensed phases. Rather, this most likely reflects a failure of
these methods to predict the frequencies well, and applying a scale factor could improve agreement with the higher frequency modes.

Lewis Acidity

The difference in Lewis acidity between BH₃ and BF₃, at least in terms of their affinity for nitriles, is extreme. This can be rationalized via physical properties of BH₂ and BF₂; electrostatics, orbital energies, and pyramidalization energies. According to B3LYP/6-31+G (d), the atomic charge (NBO) for boron on BF₃ is 1.51e, but the boron of BH₃ has close to no charge (0.04e). A larger charge on BF₃ favors electrostatic interactions between BF₃ and nitrile donors. Orbital energies, however, indicate BH₃ is a stronger Lewis acid. The BH₃ LUMO lies at -2.16 eV, -1.61 eV lower than the BF₃ LUMO. Additionally, BH₃ has an HOMO-LUMO gap of 7.3 eV, while BF₃ has an 11.5 eV gap. The smaller gap makes BH₃ a softer Lewis acid. Presumably, nitriles are softer than NH₃, which may explain why the nitrile-BH₃ complexes are bonded more strongly than NH₃-BH₃. We examined the pyramidalization energy for NH₂-BH₃ and NH₃-BF₃. Because boron is pi bonded to the fluorines, BF₃ is much tougher to pyramidalize. BH₃ is more likely to interact under these conditions. Initial electrostatics show BF₃ is likely to interact with nitriles; however all other physical properties favor nitriles to interact stronger with BH₃.

Conclusions

We examined nitrile-BH₃ complexes via DFT methods and MP2 with aug-cc-pVTZ basis set, and compared them to the analogous BF₃ systems. Borane-nitrile complexes do not exhibit medium-dependent structural change. The systems have fairly strong gas-phase B-N bonds, even shorter than the B-N bond for NH₂-BH₃. Looking at the solvation effects, the B-N distance does not compress in dielectric environments. The bond potential for HCN-BH₃ is normal, which supports the hypothesis that these complexes are structurally medium independent. Furthermore, the binding energies for these nitrile-BH₃ complexes are two to three times larger than the binding energies for parallel nitrile-BF₃ systems. We were unable to compute frequencies for nitrile-BH₃ systems, and no systematic frequency shift between BH₃ monomer and BH₃ complex. These systems do not have an unusual potential curve. All of these aspects lead to the conclusion that nitrile-BH₃ systems have no medium-dependent structural changes.

References

6) RCN
The *Augusta Portrait Series*: Capturing the Essence of Experience Etched in Age

by

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Inspiration

The *Augusta Portrait Series* draws inspiration from my artistic heritage. My great-great grandfather, Matthew Stensen, immigrated to the United States from Norway in the later part of the 19th century. Matthew desired work as a pastor, but when he could not find employment in the church, he supported his family by selling his paintings. His artwork has become a family heirloom, and because his paintings have been passed through the generations, he is the ancestor about whom my family knows the most. Matthew continues to live through his art.

Similar to Matthew’s work, my art will, I hope, continue to tell my story long after I pass. My future grandchildren and great-grandchildren will someday have the chance to discover a more personal side of me. Just as much as my own story, however, I hope to preserve the subjects in my artwork. My first creation within the *Augusta Portrait Series* is a painting of my grandfather, Grandpa Iner Stensen. In deciding on him as subject, I chose a person two generations from Matthew, just as I am two generations from Iner. His portrait is the next family relic that can be passed on to future generations. When I began the portrait, my only focus was to depict Iner accurately. But what does “accurate” mean? As I proceeded further into the painting, I realized that the contours of his face described much more than his immediate physical appearance. All of his wrinkles and blemishes reflected years spent farming in the sun. As such, the painting symbolizes endurance and a lifetime of hard work.

*Grandpa Iner.* Acrylic on canvas. 28” x 34”

*Iner Stensen, Jnr.* Oil on pine. 28” x 36”

Following my grandfather’s portrait, I sought to explore further the idea that as a person’s face ages, certain aspects of their character settle on and into that surface. The *Augusta Portrait Series* consists of five portrait paintings that explore in the faces of four elderly people selected from my hometown of Augusta, Wisconsin and surrounding area the relationships between age, identity, and
the physical environment. By painting their portraits, I hoped to capture essences of wisdom and longevity--qualities that transcend the physical--within their physical appearances. I also hoped to create an homage to their long life that they, their families, and my community could enjoy.

*Donna.* Oil on pine. 28” x 36”

*Don.* Oil on masonite. 30” x 38”

*Al.* Oil on masonite. 36” x 48”

**Method**

The portrait of Don can serve as an introduction to the techniques I used to create all the works in the Series. In designing the painting of Don, I selected the best photograph from a series, and gridded the 8” x 11” photo using 1/2” increments. I then cut and gridded a masonite board to the same proportion as the reference photo, and created a drawing on the board. The squares allowed me to draw a more accurate sketch because I could focus on drawing the image in each individual square rather than the whole photo at once (Figure 1). After drawing the image in pencil, I painted the board with a semi-transparent underpainting, so that I maintained my drawing. This was the base color from which I gradually built up the value range and color. This first layer also allowed a stronger color harmony within the piece (Figure 2). Using darker colors, I slowly built the structure and volumes in the form. Initially I laid down the darker areas and then
worked with lighter colors and values (Figure 3). After I had the value range in the painting fairly defined, I started to add in more layers of transparent color. I only used the reference photo as an initial starting point for structure, and pushed the range of color, value, and detail in the painting. Sometimes I also added in extra things that weren’t in the photo to strengthen the content of the painting and tell more about the subject (Figure 4).

![Figure 1. Progression of Don: Step One.](image1)

![Figure 2. Progression of Don: Step Two.](image2)

![Figure 3. Progression of Don: Step Three.](image3)

![Figure 4. Progression of Don: Step Four.](image4)

**Reflection**

Aristotle claimed, “Art completes what nature cannot bring to finish,” yet my work on the *Augusta Portrait Series* made me confront nature as artist, and what that artist brought forth on five human faces. The *Augusta Portrait Series* initiated my investigation of nature’s “hidden rules” of evolving proportion, color, and pattern—like fractals giving rise to animate shapes and the circulatory systems of mammals. Exploring these patterns, I hope to expand my current three-dimensional vision to a deeper understanding of how humans take part, rather than stand apart, from their surrounding environment.
Micro-wire Interconnect Fabrication Using Magnetron/DC-Triode Sputtering

by

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Abstract

Our research efforts are directed towards increasing the speed of integrated circuits. An integrated circuit (IC) is a small chip consisting of thousands or millions of interconnected semiconductor devices. Among the most advanced integrated circuits are the microprocessors that drive everything from computers to cellular phones. The specific goal of our research project is to refine the process by which micro-wire interconnects are fabricated. Interconnects are micro-meter sized wires that connect the components on an integrated circuit. By modifying a magnetron sputtering thin film deposition system to include a DC-Triode ion source, we are able to explore process parameters that are not possible with other systems. In particular, we incorporate Ion Beam Assisted Deposition (IBAD) with the magnetron sputtering system in order to alter the way that metal is deposited on the silicon wafer. We utilize that varied sputtering rate with respect to ion incident angle in order to prevent open circuit voids from being drawn inside the micro-wire.

Integrated Circuit Interconnect Fabrication

IC interconnects are electrically conductive metal wires that are built into a silicon wafer. The interconnects allow signal routing between IC devices such as transistors, capacitors and resistors. In order to fabricate a metal wire in a silicon wafer, small trenches are etched into the surface by a plasma processing and then are subsequently filled with conductive metal through any number of metal deposition techniques (Figure [1]). Integrated circuit wafers are made out of semi-conductor materials such as silicon (Si), germanium (Ge) or gallium arsenide (GaAs) or insulating materials such as silicon dioxide (SiO₂) or silicon nitride (Si₃N₄). The metal deposition normally consists of a thin metal film deposited on the surface of the wafer until the trenches are filled. Once enough metal is deposited on the wafer, the final step is then to remove excess metal from the surface of the wafer (Figure [2]).

Aspect Ratio

Aspect Ratio is defined as width/depth. This quantitative description helps to describe the geometry of any feature. Figure [3] demonstrates various aspect ratios from 1 to 3. Low aspect ratios are desirable because they are easier to fabricate. High aspect ratios, on the other hand, are desirable when more interconnects must be fabricated on a smaller chip. This effect is two-fold in modern industry because consumers want more complex devices that are also smaller in size.

A very important factor in fabricating an IC interconnect is resistance. The resistance of any wire is inversely proportional to its cross sectional area; therefore, the cross sectional area must stay the same in any aspect ratio. For example, an interconnect that is 400nm wide and 100nm deep has the same cross sectional area as one with a width of 100nm and a depth of 400nm. These two wires would have aspect ratios of 0.25 and 4 respectively.
Figure [1]: Trenches etched into a silicon wafer. The image on the left is a higher magnification side profile of the trench. The image on the right shows a low magnification oblique view.

Figure [2]: Interconnect Formation: 1. Deposit metal film on semiconductor the right wafer. 2. Continue deposition until trench is filled. 3. Remove excess metal from surface of water.

Figure [3]: Trench aspect ratios ranging from 1 (left) to 3 (right).

Initial Results using Magnetron Sputtering

A magnetron is a device that is often used to deposit thin metal films through a physical vapor deposition (PVD). A magnetron uses cylindrical magnets to confine gas ions inside a toroidal plasma. The ions are then accelerated into a metal disk (also called the target) by a voltage potential. The incoming ions eject atoms from the metal disk creating a mobile vapor that deposits on the desired surface (Figure [4]). In a preliminary experiment, a thin film of aluminum was deposited on top of a silicon wafer using only magnetron sputtering (Figure [5]). Experimental Parameters as follows: sputtering potential=600eV, power=75W, sample temperature=C, Argon press=10^{-2} Torr. Scanning electron microscopy shows a large void formation inside the interconnect trench. Such a void would lead to open circuit failure of the device and is very undesirable. Furthermore, a buildup of deposited material around the top part of the trench prevented further deposition from taking place. A number of factors could lead to this deposition behavior, such as the angular distribution of sputtered particles from the magnetron and bonding characteristics once the mobile atoms come in contact with the silicon substrate. It is possible, however, to modify the grain structure of the metal thin film during or after the deposition process. One method of modifying metal thin films is called Ion Beam Assisted Deposition (IBAD).

Ion Beam Assisted Deposition (IBAD)

Ion Beam Assisted Deposition (IBAD) is a method by which structural modifications can be made to a metal thin film during or after deposition. To achieve this goal, gas ions are accelerated from confined plasma toward the metal thin film. The collision cascade of ions into the thin film causes the grain boundaries to rearrange and it also ejects particles (see the next section “Re-sputtering and incidence angle” for more information). The effect of atoms being ejected from the metal thin film is called re-sputtering.

In our system, both plasma density and sputtering potential could be adjusted indepen-
dently from magnetron operation. Typical re-sputtering parameters ranged from 50 to 100 eV and 0.5 to 2.0 mA/cm² plasma density. Figure [6] shows the effect of re-sputtering on a test wafer.

**Figure [4]:** Component placement in the magnetron/DC-Triode system.

**Figure [5]:** Preliminary result using only magnetron sputtering.

**Figure [6]:** A graph of sputtering rate vs. incoming ion angle of incidence.

**Figure [7]:** Erosion of a trench corner as a result of re-sputtering.

**Re-sputtering and incidence angle**

Figure [6] shows the heavy dependence of sputtering rate with respect to incoming ion angle of incidence. Ions that collide perpendicularly with the surface will cause fewer particle ejections, while ions that collide at glancing angles will cause more particle ejection. This attribute can be exploited in order to clear away excess buildup of deposited metal around the trench opening. On the corners of the trenches, incoming ions will have an angle of incidence near 90°. This will lead to a dramatic increase in re-sputtering rate around the corners of the trenches. Figure [7] shows the effect of re-sputtering on a test wafer. Note from this sample that the silicon wafer is damaged from excessive re-sputtering. The figure demonstrates the significance of incoming ion incidence.

**A Test of Ion Beam Assisted Deposition**

Before integrating IBAD with our system, we deemed it important to perform an operational check of the theory. In order to conduct this experiment, a thin film of aluminum was deposited on the surface of a silicon test wafer. The sample was then re-sputtered until the metal
thin film on the surface of the wafer was removed. The result was a notching of the trench corners corresponding to the higher sputtering yield at high angles of ion incidence. In the preliminary experiment, part of the silicon wafer was damaged—clearly an excessive re-sputtering rate. This means that the re-sputtering rate must be optimized to match other system parameters such as type of metal thin film, deposition rate and the amount of thin film already deposited.

Figure [8] shows a comparison of samples prepared with and without IBAD re-sputtering. The left image shows a sample trench deposited with an aluminum thin film corresponding to the trench depth and no re-sputtering. The right image shows a sample trench that was deposited with the same amount of aluminum, but was re-sputtered with the IBAD system. This sample trench remained open for the duration of the experiment and has significantly more metal inside the trench. While this experiment was still unsuccessful due to the large void inside the trench, it is, however, a significant improvement over the original trench fill experiment. This experiment also highlights the need to optimize the amount of re-sputtering to fit other system parameters. In order to successfully fill the trench, a “recipe” must be formulated with the proper amounts of sputtering and re-sputtering. Future research will focus on optimizing the procedure in order to properly fill the IC interconnect trenches.

![Image](image_url)

**Figure [8]:** The image on the left demonstrates deposition with a magnetron alone. The image on the right demonstrates combined magnetron and IBAD use.

**Industrial Application**

A current production technique for high aspect ratio interconnects uses layering techniques to avoid the problems associated with filling a deep trench in a single step. Figure 9 is a photo released by Intel in August 2004, that shows 8 layers used to obtain an overall aspect ratio of about 7:1. With this technique, the interconnect is fabricated on several layers, each of which must be exactly placed on top of the previous one. The inherent problem with this process is an increased number of fabrication steps, increasing the chance of failure during fabrication. In the end, both product and profit are lost. Our technique can lead to a reduction in number and complexity of fabrication steps, which will then translate into a decreased number of failed components.

**Transmission Electron Microscopy**

Transmission Electron Microscopy (TEM) is a very powerful tool in any nanotechnology research area. TEM imaging enables researchers to resolve items as small as 0.1 nm (1x10^-10 m). At this level of magnification, grain structure and grain boundaries are clearly visible. Figure [10] demonstrates the high resolving power of a TEM. In this image, the grain structure of deposited aluminum is clearly visible along the inner wall of the interconnect trench. These grains, also known as dendrites, are angled upward towards the mouth of the trench. This grain structure is a significant contributor to the buildup of material around the opening of the trench, which in turn causes...
void formation during deposition. Future research includes an investigation of dendrite structure with respect to the thin film deposition temperature.

**Figure [9]:** Layered interconnects used by Intel.

**Figure [10]:** Image acquired with Transmission Electron Microscopy showing grain structure along trench wall.

**Conclusions**

Our research demonstrates the impact of re-sputtering on IC interconnect trench metallization. IBAD makes a significant impact on the deposition of metal in high aspect ratio interconnect trenches. This could lead to a simple and cost effective modification to existing commercial systems that make IC interconnects, enabling them to make more complex ICs without fully replacing their existing machinery.

TEM imaging of deposited thin films shows the grain structure of deposited metal thin film. A more complete investigation of the thin film grain structure could pave the way to make higher aspect ratio IC interconnects without failure from void formation.

**References**


Plant Traits During Prairie Seedling Establishment

by

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Abstract

Understanding the establishment of certain prairie species could greatly assist the successful restoration of certain ecosystems. By examining the traits of certain invasive species, as well as their establishment, we will gain insight regarding the best mechanism to employ when introducing native prairie species (Wilson). Our study seeks to determine whether the establishment rate of seedlings provides them advantages against invaders in regard to fecundity, competitiveness and health. Seedlings included ten plant species (*Ambrosia artemis*, *Chenopodium album*, *Capsella bursa*, *Acalypha rhomboidea*, *Lupinus perennis*, *Plantago major*, *Solidago Canadensis*, *Setaria glauca*, *Polygonum scandens*, and *Polygonum persicaria*) in disturbed quadrats in an experimental grassland area. The quadrant of 64 m² was divided into four smaller sections of 4 m²; each section contained four replications of randomly placed seedling locations. The quadrant was treated with *Roundup*, then raked to eliminate biomass. We did this to mimic a natural disaster, such as a fire. However, no matter how hard we tried, it proved nearly impossible to exactly simulate a natural disaster in every aspect. Seeds were planted, and throughout the summer traits were measured. These traits included stem diameter, plant height, leaf breadth and overall biomass. We hypothesized that species that establish early in highly disturbed areas have distinctively different traits as compared to those that establish later. These traits would include higher chlorophyll and surface leaf area (SLA) levels, more growth per week, and larger plant area overall. In the presence of fungicide, these differences would be even more evident.

Materials and Methods

A 64 square meter plot was treated twice with *Roundup*, then raked to remove biomass. Seeds of native target species were planted in the plot. After a few weeks, it was apparent that very few, if any, of the target species were going to germinate. We decided to perform the tests and observations on the invasive, non-native species. Four plants in each plot were marked with plastic tape, for a total of 512 plants overall. The non-native species included *Ambrosia artemis*, *Chenopodium album*, *Capsella bursa*, *Acalypha rhomboidea*, *Lupinus perennis*, *Plantago major*, *Solidago Canadensis*, *Setaria glauca*, *Polygonum scandens* and *Polygonum persicaria*. As it turned out, *Lupinus perennis* was the only non-native species that successfully germinated. This success was contributed to its large seed mass; seeds of *L. perennis* were the largest of all species studied. Westoby *et al.* showed that seedlings of larger-seeded species are better able to survive hazards such as deep shade, resource competition and dry environment. This phenomenon, known as the "reserve effect," may help explain why only one of our target seedlings germinated in our study (Westoby *et al.*).

Height, breadth, stem diameter, chlorophyll and mass were measured weekly on plants in fungicide and control (Jutila). Plots were uniformly irrigated during seasonally dry periods. Fungicide (chlorothalonil) was applied twice throughout the growing season to reduce soil fungi—in particular

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mychorrhizae—as well as other fungi that may either inhibit or contribute to overall plant growth (Wilson). Leaves were collected, one per plant, twice during the season. These were used to measure the surface leaf area (SLA) (Figure 1).

![Figure 1. Mean surface area (SLA) in cm²/g. Surface leaf area was calculated by dividing Leaf Area by Leaf Dry Mass. Species included: Chenopodium album, Polygonum scandens, Solidago Canadensis, Polygonum persicaria, Setaria glauca, Plantago major, Lupinus perennis, Capsella bursa, Acalypha rhomboidea and Ambrosia artemis.](image1)

![Figure 2. Mean chlorophyll values (µg/cm²). Species included all of those listed in Figure 1. Letters denote statistical differences among species (Tukey, p<0.05); bars with same letters are not different.](image2)

![Figure 3. Mean plant breadth (length multiplied by width, cm²). Significant difference between those grown in control plots and those grown in plots with fungicide (p<0.05). Species included: Acalypha rhomboidea, Ambrosia artemis, Chenopodium album, Lupinus perennis, Plantago major, Polygonum scandens, Setaria glauca, and Solidago canadensis.](image3)

**Results**

Four main trend groups were apparent in the mean SLA values (Figure 1). Three main trend groups were apparent in chlorophyll values (Figure 2). These trend groups may support the statement that by having certain traits, a seedling may possess certain advantages over others during different conditions. There was a significant difference between mean plant area of species grown in the control plots compared to those grown in plots with applied fungicide (Figure 3). Four main trend groups were apparent for height amongst the species, and there was a trend of taller plants in the fungicide treated plots versus untreated control plots (Figure 4). This was an unexpected result and more research could be done to determine why the plants grew taller in the presence of fungicide. Also the four height groups may be explained by the different niches in which these specific species became accustomed. Three main trend groups were apparent for stem diameter and the values were very similar in both the untreated control and the fungicide (Figure 5).

**Conclusions**

The data support that the differences are more evident in the presence of fungicide. Though
Figure 4. Mean plant height, measured at the highest point, including arc of leaves (cm). Species included all of those listed in Figure 3. Results were not significantly different; however, there does seem to be a trend in the height differences (p<0.05).

Figure 5. Mean stem diameter, measured approximately 5 cm off the ground (cm). Species included all of those listed in Figure 3. Results were not significantly different; on the contrary, they are very similar between the untreated control and the fungicide groups (p>0.05).

there were no significant differences in stem diameter and height between the control and fungicide plots, there were significant trends in the grouping of the results. More research needs to be done, especially once target species germinate, since this research was done on the early establishing nonnative species. These group trends may support the statement that early establishing plants occupy certain niches in order to utilize the maximum resources in those niches.

We may have obtained different results had we tilled the soil before planting the seeds. Our reasoning for not tilling the soil was to closely resemble a primary succession prairie (i.e., what would happen after a fire has burned a section of land) (Holmes). Thus, this study could be replicated after a fire has disturbed a plot, which is identical to real life events. Another parallel study could be done in the greenhouse to determine different traits of plants not limited by competition.

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Resources


The Effect of Nonphotic Stimuli on the Circadian Rhythms and Estrous Cycles of Female Syrian Hamsters (Mesocricetus auratus)

by

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Abstract

Female hamsters normally have a precise four-day estrous cycle. We have found, however, that changing the cage of a female hamster—a nonphotic circadian clock resetting stimulus—in the middle of the day before it ovulates not only resets the hamster's circadian clock by about three hours, but it also delays its estrous cycle by one day. Cage changing arouses the hamster, and causes it to engage in much locomotor activity. Two experiments were conducted to examine the interaction between circadian clock resetting, locomotor activity, and the estrous cycle. In the first experiment we blocked the activity of females after a cage change either by locking their exercise wheels or by restricting them to a nest box. This experiment was a test of whether clock resetting without activity can induce an estrous delay. In the second experiment we explored whether Phenobarbital, an agent known to delay estrous, also causes clock resetting. Animals treated with Phenobarbital (100 mg/kg) showed significantly greater resetting than controls. As predicted, all Phenobarbital-treated animals showed an estrous delay and none of the control animals did. Furthermore, we found that the beta-adrenergic antagonist propranolol (20 mg/kg) blocked circadian resetting induced by Phenobarbital, but did not block the estrous delay. These results support the idea that circadian clock resetting associated with nonphotic stimulation is not required to induce an estrous delay.

Introduction

Female Syrian hamsters normally have a very regular four-day estrous cycle. In the past, little research explored the relationship between the estrous cycle and the circadian clock of these organisms. Several manipulations have been shown to produce a significant phase shift (≥ 1.5 hours) in male hamsters. Some of these manipulations include gentle handling (Antle and Mistlberger, 2000), as well as a variety of photic (light-related) stimuli. Previous work has shown that changing a female hamster's cage on the day before ovulation (proestrus) can induce a shift of its circadian clock. When a hamster's cage is changed, it typically becomes very active over the next two to three hours. When an individual hamster experiences a phase shift, in most cases, its estrous cycle is then also delayed by one day. We wanted to explore the relationship between the delay of the estrous cycle, the behavioral activity and clock resetting. Overall, we wanted to know whether an increase in activity or the resetting of the circadian clock causes the estrous delay. In order to find this, we performed two non-photic pulses, the first restricted activity by either locking the exercise wheel to prevent running or confining the individual to a nest box to restrict movement all together. This was intended to show if activity is necessary for an estrous delay. The second pulse used injections of both propranolol and Phenobarbital. Propranolol, a beta-adrenergic blocker is a drug known to reduce clock setting, but which does not reduce activity. Phenobarbital is a barbiturate that causes a delay in the estrous cycle, but whether it has an effect on the circadian clock remains unknown (Alleva and Umberger, 1966). By varying these interventions we attempted to show whether or not a phase shift is necessary for an estrous delay.
Materials and Methods

Female Syrian hamsters were housed in polypropylene bucket cages (25×46×20 cm) with stainless steel mesh lids and running wheels 17.5 cm in diameter. The wheels were lined with black plastic mesh in order to reduce foot injuries and increase activity. A magnet was attached to each wheel. Each wheel revolution triggered an electrical switch that was affixed to the outside of the cage. The numbers of wheel revolutions per hour were collected by the Datacol III data collection and analysis system. Food and water were available at all times to the hamsters, and the temperature in each room was maintained at 19-21 degrees Celsius. The estrous cycle of each individual hamster was determined by performing daily visual checks for vaginal discharge (Orsini, 1961) and followed the estrous characteristics defined by Lisk (1985). Estrous cycle was monitored for at least 20 days prior to each manipulation to ensure the cycle was determined correctly. All of the individual hamsters used were bred in the lab from breeding stock from Harlan Sprague Dawley (Madison, WI).

Experiment #1

Methods

Twenty-two animals were kept in a constant light cycle of 14 hours of bright light (300 lux ± 50 lux) and 10 hours of dim light (0.75 lux ± 0.25 lux). The individual hamsters were randomly chosen to receive one of three treatments. Two groups contained seven hamsters and the third contained eight. On the day of proestrus at ZT 4.5 each animal received its respective manipulation and was put into 24 hours of complete darkness for three days. The animals of the first group (control) were given open nest boxes (slightly larger than the hamster) made of polypropylene and wire mesh. The animals of the second group had their exercise wheels locked in place to prevent running, and the animals of the final group were confined to nest boxes with food and water. Each individual hamster remained in these conditions for five hours following the pulse time, after which their cages were returned to normal conditions while remaining in complete darkness.

Results

Only two of the control hamsters phase shifted and three had a delay in estrous. In both the locked wheel and nest box treatments, five animals had a significant phase shift and only one had a delay in estrous. In these two treatments, no correlation was found between the circadian clock and the estrous cycle (Figure 1).

Discussion

We did not receive the results necessary in order to support the hypothesis that activity is necessary for a phase shift, and in turn estrous delay. We expected all of the control animals, those whose activity was not restricted, to shift. We also expected the locked wheel and nest box animals not to shift or shift estrous. Activity, evidently, is not the only component necessary for a phase shift. Possibly phase shift works in unison with some other factor that we have not yet taken into account. In the future, the experiment will be performed again in order to discount human error and the protocol will be edited.

Experiment #2

Methods

Eighteen animals were kept in a constant light cycle of 14 hours of bright light (300 lux ± 50 lux) and 10 hours of complete dark. Individual hamsters were randomly chosen to receive one of three treatments, and six animals were used in each treatment. On the day of proestrus at ZT 4.5, each animal received its respective injection. All injections were given subcutaneously. The first group (control) was injected with 0.1 ml sterilized Nanopure water, the second group received...
100mg/kg Phenobarbital in 0.1 ml water, and the final group received 20mg/kg propranolol in 0.2 ml water followed by an injection of 100 mg/kg Phenobarbital in 0.1 ml water. Following the injections, the animals were put into 24 hours of complete darkness for three days.

Figure 1. The mean phase shift for each treatment. No significant difference was found between any of the treatments. Error bars represent the amount of one standard deviation.

Figure 2. The mean phase shift for each administered injection. There was a significant difference found between all three (p<0.05). Error bars represent the difference found between all three (p<0.05).

Results

None of the control animals showed a significant phase shift; neither did they show an estrous delay. All of the animals that received only an injection of Phenobarbital showed significant phase shifts (≥2.84 hours) along with a one-day delay in their estrous cycle. However, none of the propranolol/Phenobarbital animals showed a phase shift, but their estrous cycle was delayed by one day (Figure 2).

Discussion

Phenobarbital induced a significant phase shift in all of the animals receiving it, and in turn, these animals also experienced a one-day estrous delay. In the animals receiving two injections, one of propranolol and one of Phenobarbital, the effect of Phenobarbital (phase shift) was blocked by propranolol and the animals did not show a phase shift. However, these animals did still show a one-day delay in estrous. These findings were very surprising because each individual hamster within each treatment exhibited the same result. This shows that a phase shift is not necessary for an estrous delay. In future these results will be used to examine the relationship between the phenomenon of estrous cycle delay and the circadian clock.

Literature Cited


