

CREATING KNOWLEDGE

The LA&S Student Research Journal



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The College of Liberal Arts and Sciences Student Research Journal

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Letter from Dean Suchar	5
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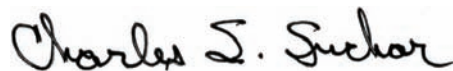
Dunker versus Dunker: Comparing Perspectives on a Catholic Life.....	6
Mark Bychowski	
Kerala Catholicism in the U.S.: Perspective, Community, and Catholicity.....	10
Benita Antony	
Fudo Myo-o.....	13
Vanessa Morales	
Guanyin and Shukongo-jin: Deities in the Buddhist Pantheon.....	17
Adrianna Teolis	
Re-Presenting Feminist Art: Macena Barton (1901-1986) and Her Representations	20
Jamie Shaw	
Bystander Art: Hannah Höch's Nazi Years.....	24
Lauren Young	
Beyond Reconquista and Convivencia: The Relevance of Hispano-Arabic Identity for a Post-Islamic Spain.....	28
Nicholas R. Lang	
Online Agression/Victimization and Adjustment among Emerging Adults.....	32
Jessica E. Twardowski, Clare L. Kennedy and Michelle F. Wright	
The Influence of Reader Goals and Textual Constraint on Predictive Inference Generation in the Cerebral Hemispheres.....	36
Lauren Schliesleder and Laura Motyka Joss	
Violating Traditional Gender Roles: The Effects of Perceived Symbolic Threat on Rationalizing Intimate Partner Violence	40
Cassandra Esposito	
Childhood Experience and Pro-Environmental Behavior.....	44
Aleksandr Pevtsov	

The Impact of Different Types of Environmental Messages on Dormitory Residents' Energy Conservation Behavior	48
Marian Vernon	
Synchronizing a System of Coupled Oscillators	52
Brent Allen May Jarvis	
Femtosecond-to-Nanosecond Clocking Using a Double-Slit Optical Encoder	56
Jakub Kolacz and Abraham Burleigh	
Weather Balloons: Constructing an Onboard Data Recorder for Upper Atmospheric Research	59
Nicole Sprenger	
Non-Gaussian and Anisotropic Signatures in the Cosmic Microwave Background	65
Sarah J. Washburn and Jennifer Smith	
Marine Vertebrates from the Upper Cretaceous Heartland Shale in Southeastern Colorado	69
Matt Nagrodski	
The Relationship between Isoprene Stimulation and Photosynthesis Reduction during Drought Stress in Cottonwoods (<i>Populus deltoides</i>)	73
Caitlin Schulze	
Degradation of Ailanthone, an Allelopathic Chemical Produced by <i>Ailantus altissima</i> (Tree of Heaven)	77
Reid Gustafson	
The Effects of Multiple Mycorrhizal Fungi on Perennial Prairie Plants and the Mutualistic Implications	81
Erika Spencer	
The Effect of Mycorrhizal Fungi on <i>Plantago virginica</i> in Drought Conditions	85
Hemal Patel	
The Effect of Mycorrhizal Fungi on Annual Prairie Plants in Drought Conditions, with a Focus on <i>Plantago aristata</i>	88
Stephanie Hughes	
The Effect of Genistein Plus Estradiol on Apoptosis.....	92
Kevin Peine	

DEAR STUDENTS, FACULTY COLLEAGUES, AND FRIENDS,

The College of Liberal Arts and Sciences, through the deliberations and efforts of its Task Force on “Creating Knowledge,” chaired by Professor Ralph Erber, Associate Dean for Research in the College of Liberal Arts and Sciences, committed itself to a number of new strategic initiatives that would enhance and enrich the academic quality of the student experience within the college. Chief among these initiatives was one that would encourage students to become actively engaged in creating scholarship and research and give them a venue for the publication of their essays. The first volume of *Creating Knowledge: The LA&S Student Research Journal* was published in 2008 followed by the second volume in 2009. I am now extremely pleased to be able to introduce the third volume of *Creating Knowledge*. It is through the continuing, annual publication of this undergraduate student journal that we aim to encourage students across the college and the university to understand that leadership within their disciplines requires them to not only be familiar with the knowledge base of the discipline, but to have the experience of being actively engaged in understanding how creative work and/or scientific discoveries are created through research, scholarship and the dissemination and sharing of knowledge.

I want to congratulate, first and foremost, the many student scholars whose work is featured in this third volume of the journal. I also want to thank the students and faculty who served to make this publication possible—those who served on the editorial board that shaped this journal and who reviewed the many submissions of student work. In accomplishing this task all of you have participated in what is the heart of scholarship—the contributions to enabling and sustaining an intellectual community—one which we hope will lead you to make similar contributions beyond the college and DePaul University. To one and all, my most sincere congratulations and gratitude.

A handwritten signature in black ink that reads "Charles S. Suchar". The signature is written in a cursive, slightly slanted style.

CHUCK SUCHAR
DEAN

Dunker versus Dunker: Comparing Perspectives on a Catholic Life

Mark Bychowski*

Abstract The autobiography and letters written by Reverend Wendelin Dunker preserved in the Special Collections and Archives of DePaul University include descriptions of his experiences in China during World War II and the Communist Revolution. There is a consistency of facts in these manuscripts, but distinctions arise. It is unclear why Dunker reveals an abundance of information about military activity in the autobiography, while he remains relatively silent on these issues in the letters. The disparity in information may stem from a change in perspective; in looking back at the events of his life he may have gravitated towards retelling the military exploits. Alternatively, the disparity may stem from Dunker's concerns about confidentiality and releasing military information.

Introduction

In 1974, Reverend Wendelin Dunker, C.M., a Catholic priest and Vincentian missionary, wrote an autobiography entitled *The Life of Wendelin Joseph Dunker*, in which he related his work in China from 1933 to 1956. Dunker also created an autobiographical audio-recording circa 1989. His account included specific descriptions of his experiences in the Chinese-Japanese conflict during World War II and immediately following the Communist Revolution. The manuscript is currently preserved in a personnel file in DePaul University's Special Collections and Archives.

In addition to the manuscript, Dunker's personnel file also contains 60 letters that he wrote to fellow ecclesiastics, friends, and family from 1933, when he arrived in China, to 1950, six years prior to his return to the United States. In the correspondence, Dunker provides details and commentary on events shortly after they occurred. Unlike the autobiography, excerpts of some of these letters have been edited and published in Vincentian newsletters, such as *The DeAndrein*. As several of the letters reveal, however, Dunker was not pleased with the editors' work, criticizing them for putting very little of what he wrote into *The DeAndrein* and for distorting his message (Letter 3, pg. 1).

Dunker's criticism draws attention to a central dilemma in constructing a history: distinct sets of sources and levels of editing provide distinct visions of an event. What is available from the autobiography and the letters is exactly that: two visions of the same events, provided by the same author, at two different times in his life. One looks back some 30 to 40 years, while the other is from immediately after their occurrence. Furthermore, the autobiography and the letters were written in two completely

different styles with distinct audiences in mind. The former was composed as a narrative for a general reader; the latter for a select individual or group, only a few letters with the intent of wider readership. Comparing and contrasting the two visions brings a clearer image of the events into focus: specifics can be verified, information better explained, and personal perspective charted.

For relevance and manageability, I selected letters from the years 1940 - 1949 for comparison, since the decade of the 1940's makes up approximately forty percent of the available correspondence and incorporates a series of important events, including the Doolittle Raid, the escalation of the China-Japanese conflict, and the roots of the Communist Revolution. This period makes up 49 pages of the original manuscript of Dunker's autobiography. Furthermore, I selected the letters written to fellow ecclesiastics rather than those written to family members because I assume that the letters to fellow ecclesiastics contain a greater amount of relevant information.

The Parallels

Instances in which information in the correspondence matches or confirms the narrative of the autobiography are the most apparent bridges between the two sources. However, the number of events mentioned in the autobiography that also appear in the correspondence is relatively minimal. Those that do primarily relate to the structure of the mission in Ihwang, traveling conditions, Dunker's vacation, and financial difficulties.

Parallel 1: The Mission in Ihwang

From 1933 to 1949, the majority of Dunker's time in China, he ran a mission in the town of Ihwang. He describes Ihwang in the autobiography, and corroborates these descriptions in the

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correspondence. Both mention the location and consistently use the town as the return address.

In his autobiography, Dunker gives a general description of the parish and his duties there. He states that “there were usually two priests in Ihwang” (Autobiography, pg. 11). The period of their work, according to the autobiography tended to be “during the fall and most of the winter” (Autobiography, pg. 11). Dunker goes on to qualify that he and the other priests would make a particular effort to visit the larger missions in the parish during “Christmas, Easter, Pentecost, and the Assumption” (Autobiography, pg. 11).

His letters provide greater specificity about the information contained in the autobiography. He provides more detail about his fellow priests by saying that he served with “Father Yager” and later with “Father Leo Moore” (Letter 4, pg. 2). The correspondence clarifies the frequency of their visits, explaining that they could only make missions twice a year, “one is the late fall and winter when the Catholics have time, and one is for a month or so around the 15th of August when they have a bit of time” (Letter 13, pg. 2). The correspondence confirms the times of large Masses, explaining that “since Sundays do not have the meaning they should, four special feasts are set aside to be celebrated in a solemn and special manner. These feasts are: Christmas, Easter, Pentecost, and the Assumption” (Letter 11, pg. 1).

Parallel 2: Travel

The difficulty of travel is commented on several times in the autobiography and the correspondence. The Ihwang parish was particularly difficult for Dunker to traverse. In the autobiography Dunker explains that “Ihwang parish was about 50 miles long and 30 wide, and our missions were scattered all over this area” (Autobiography, pg. 12). The road that Dunker had to travel on was in particularly poor condition, which in the autobiography he attributes to the fact that “not too long afterwards when the Sino-Japanese War was heating up, it was dug up to prevent the Japanese from using it if they were to come”. Traveling, the autobiography explains, was typically difficult and slow even without the problem of a damaged road because “the mode of transportation we had was either to walk or horseback or by bicycle provided you were rich enough to own a horse or a bicycle. I owned a bicycle and about all I can say about it is that it was somewhat quicker and easier than walking” (Autobiography, pg. 12). The autobiography goes on to note that bicycle travel, which was faster than walking, was hard too, because “you had to get off the bike about 30 times to a mile to cross rivers, gullies, breaks in the road, etc.” (Autobiography, pg. 12).

The vast distances of the parish are attested to in the correspondence when Dunker writes that he, “recently had [his] farthest sick call. 40 odd miles away” (Letter 1, pg. 1). The destruction of the road is a repeated topic in Dunker’s correspondence, confirming in one letter that a “couple of years ago [the road to Ihwang] was dug up and destroyed, with the idea of impeding the advance of the Japs, had they taken it into their heads to come in this direction” (Letter 11, pg. 2). He confirms his autobiographical claims about modes of travel in letter 11, where he writes, “for ninety-nine out of a hundred Chinese here in the interior, the quickest, and usually the only mode of travel, is walking” and in his case, unlike in the United States “instead of an auto I have to bicycle” (Letter 11, pg. 2). On the subject of bicycles, the letters explain that on the way to a mission there is a “road that is passable for bicycles in dry weather, but when I left it was raining” (Letter 5, pg. 1). In nearly all topics of travel, Dunker’s autobiography and correspondence validate one another.

Parallel 3: Money

Dunker’s observations about the rise of communism take into account financial concerns as well. The financial difficulties that dominate much of the correspondence are contextualized by the autobiography. Here the fervor of writing, as well as the details and confusion of the moment, is complemented by the distant, broader understanding of later life. In his autobiography, Dunker explains the financial problems, mainly inflation: “Another big factor enabling the Communists to take over was the fact that because of the long drawn out war, the Nationalist Government began running their money printing machines 24 hours a day, to pay for necessities” (Autobiography, pg. 37).

Inflation and the corresponding increase of prices are detailed in nearly every letter in the 1940’s collection. In them, Dunker informs his reader that “the high cost of living, high cost of commodities, etc. is due to a variety of causes, among which [several] may be numbered: the drop and weakness of the Chinese dollar; the fact that China has now been at war with Japan for four years; the Japanese blockade; escalation, and perhaps, many other reasons” (Letter 10, pg. 2).

Parallel 4: The Japanese Occupation of Ihwang

While much of Dunker’s time in Ihwang was relatively peaceful – due, he explains in both the autobiography and the correspondence to the difficult terrain and lack of tactical importance of the area – the Japanese entered the neighboring town of Fuchow in 1942. Days later, they came to Ihwang. In the manuscript, Dunker provides a dramatic account of his escape from the town and his covert return to the occupied mission house to retrieve

valuables and consume the remainder of the Blessed Sacrament (Autobiography, pg. 23-33).

Only one letter, written to Bishop O'Shea, includes a shortened version of this tale and corroborates many of the details, including Dunker's secret return to the mission house (Letter 12).

Conclusions

Broadly considered, the autobiography and the selected correspondence verify their respective accounts of people, conditions, and events. What appears most striking about the relationship between the manuscript and the correspondence is how much is mentioned in the autobiography that is not found in any of the letters around those dates. In 1943, the Doolittle Raid was undertaken in China. According to the autobiography, after the planes crashed several of the pilots turned up in Dunker's parish and he was able to help them return to base. The manuscript devotes 11 pages of text to describing the event, and yet the available correspondence completely ignores the event. By 1947, the war with Japan had ended and the Communists had begun to work their way across the countryside. As with the Japanese occupation, Dunker narrates the coming of the Communists in his autobiography with a long series of events, in this case beginning with the build-up to the occupation of Ihwang and culminating in his escape from the town. The correspondence doesn't ever mention the Communists in Ihwang. The distinct subject

matter of the correspondence is more benign and thus more easily explained. The letters describe in detail the construction of the various mission houses, the status of the mail and various subscriptions, reflections on daily life in China, and anecdotes about local personalities.

Between the retrospective nature of the autobiography and the immediacy of the correspondence, there is a consistency of facts. Distinctions arise in the degree to which content about the war is considered and shared. It cannot be answered through available sources why Dunker reveals an abundance of information about military activity in the autobiography but remains relatively silent on these issues in the correspondence. The disparity may stem from a change in perspective; in looking back at the events of his life, perhaps he gravitated towards the military exploits due to public interest in the war. Alternatively, this may stem from concerns about confidentiality or distributing military information in a time and place where such details could have ramifications for the war effort; only afterwards may Dunker have felt safe to share his accounts. In any case, the rationale for his selectivity in writing is not explicit and can only be interpreted on the basis of the information that appears in the two sources. What can be verified is that, on the whole, the perspectives and narratives of the two sources verify, and at times clarify, their respective testimonies.



Ralitz Treneva,
Still Life Painting (2010)
Oil on canvas

Kerala Catholicism in the U.S.: Perspective, Community, and Catholicity

Benita Antony*

Abstract In A.D. 52 St. Thomas the Apostle arrived in India and evangelized the Kerala region. Today, more than 100,000 St. Thomas Syro Malabar Catholics from Kerala reside in North America. The move to the pluralistic culture of the U.S. accentuates the sense in which faith shapes one's sense of self. This study investigates how a spiritual and liturgical experience of Christian faith permeates both the personal and communal identity of Kerala Catholics in Chicago and the Bronx, New York.

In multiple publications, Raymond Brady Williams, Professor Emeritus of Religion at Wabash College, has drawn attention to the contribution of Christian traditions from India to the religious diversity of the United States. But neither Williams nor any other recognized scholar in theology and religious studies has paid adequate attention to the spiritual identity of Syro Malabar Catholics in North America.¹ The most notable contribution to this unexplored area of research is a published undergraduate thesis recently completed at the University of Texas at Austin.²

This study utilizes an interdisciplinary method to examine the religious and social identity of this group. Through videotaped interviews with lay and ordained faithful, information was gathered about the experience of the rite, or the Syro Malabar faith, both as it relates to the personal identities of U.S. Kerala Catholics and as it contributes to the global richness of the Catholic Church.³ A review of the interviews revealed a number of complex, qualitative patterns that this essay organizes in a natural progression.⁴ The questions asked to the laity included: 1.) What do the Syro Malabar churches offer that the Catholic Churches of the U.S. do not? 2.) How does Keralite culture influence identity for believers in the United States? 3.) How does this situation manifest the generational gap between immigrant children

and their parents? Interviews⁵ with church officials included an additional question: "How does the Syro Malabar church contribute to the universality of the Catholic Church?"⁶ As such, the study also explores the theological concept of "unity in diversity" from the Second Vatican Council and asks whether and how Syro Malabar Catholics have testified to this concept in their experience of Catholicism.⁷

The principle of maintaining a unity in diversity of rites follows from the most basic prayers of Catholicism. In the Nicene Creed, a prayer recited at every Catholic Mass, reads: "We believe in one, holy, catholic and apostolic church." This can be described as the Universal Catholic Church. According to Monsignor Kuriakose Bharanikulangara, Counselor to the Permanent Observer Mission of the Holy See to the United Nations, "We should see The Universal Church as a communion. We are not separate."⁸

Scholars believe St. Thomas instituted the Syro Malabar rite in A.D. 52, when the Apostle came to the Malabar Coast and evangelized the southern state of India known as Kerala.⁹ St. Thomas Christians followed an East Syrian or Chaldean liturgy, and formed the rite known as Syro Malabar.¹⁰ The Syro Malabar rite, which comes from Antioch and falls under the Chaldean rite,

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1. Some significant examples of the general works on Indian Christianity include: Cardinal Eugene Tisserant, *Eastern Christianity in India* (Westminster: The Newman Press, 1957); Donald Attwater, *Eastern Catholic Worship* (New York: The Devin-Adair Company, 1945); Raymond Brady Williams, *Religions of Immigrants from India and Pakistan* (New York: Cambridge University Press, 1988); and Raymond Brady Williams, *Christian Pluralism in the United States: the Indian Immigrant Experience* (Great Britain: Cambridge University Press, 1996). Selva Raj of Albion College was prepared to undertake a study of the Kerala Catholics in the U.S. before his untimely death in 2008. Harvard theologian Susan Abraham touches upon Kerala identity in her *Identity, Ethics, and Nonviolence in Postcolonial Theory: A Rabnerian Theological Assessment* (New York: Palgrave Macmillan, 2007), 65ff. but without any consideration of the unique situation of the diaspora community.

2. Joseph, Jaisy. *The Struggle for Identity Among Syro-Malabar Catholics*. Dallas: Lulu Publications, 2009.

3. The Universal Catholic Church is composed of about 1.17 billion people from across the globe.

4. This study utilizes Clifford Geertz's notion of a "thick description," in *The Interpretation of*

Cultures the discursive responses to these questions shaped the development of generalized concepts about Kerala Catholicism in the U.S. Clifford Geertz, *The Interpretation of Cultures* (New York: Basic Books, 1973), pp. 10, 28, 30.

5. Interviews were conducted from July 2009 through November 2009.

6. The camera person and investigator videotaped 54 interviews with participants age 18 and over in the Bronx, New York and Bellwood, IL. These were communities with which the investigator had contacts. However, it is important to note the St. Thomas Syro Malabar Catholic Cathedral is located in Bellwood, IL. All participants belonged to the first or second generation of Syro Malabar Catholics. Responses of laity remained anonymous, church officials could choose to publicize their responses or remain anonymous.

7. Pope Paul VI, *Dogmatic Constitution on the Church: Lumen Gentium*, www.vatican.va/archive/hist_councils/ii_vatican_council/documents/vat-ii_const_19641121_lumen-gentium_en.html (November 1964).

8. The Universal Church is the unity in diversity of local churches and can be described as the *Church of Churches*, an idea that goes back to the origins of the Church according to Cardinal Tillard. J.-M. R. Tillard, *Church of Churches: The Ecclesiology of Communion* (Collegeville, The Liturgical Press, 1992).

belonged to the Eastern Church from the beginning.¹¹ Before the Second Vatican Council, the Syro Malabar liturgy and prayers were said in the Syriac language. After Vatican II, the faithful could worship in their mother tongue, Malayalam.¹² Vatican II affirmed the integrity of the Eastern liturgical rites and held them as high in esteem as the Roman or Western liturgical forms. Vatican II wished to uphold a unity in diversity of rite. Today, the Kerala Catholics have established forty-four Syro Malabar parishes and missions in the U.S.¹³

The first pattern revealed in interviews was the importance of experience. Interviewees were invited to explain how Kerala Catholics understand and experience their Catholic faith more explicitly in their native church. Factors such as language and the Western liturgical traditions continued to create distance between Kerala Catholics and other American Catholic churches.¹⁴ The Syro Malabar Church served as a home to Keralites in America as it had in India because in it they spoke their language and practiced their traditions. Syro Malabar in the U.S. nurtured the Eastern Christian roots of their spirituality, which allowed them to fully experience the Eucharist again. This particular Eastern spirituality has many implications for St. Thomas Syro Malabar Catholics in the United States and the world over.¹⁵ In belief, the Syro Malabar Church is consistent with the teachings of the Universal Catholic Church; in expression, the Syro Malabar Church is contemplative, orthodox and sacramental; in customs, the Syro Malabar Church resembles the popular society of Kerala.

Ample evidence in interviews showed that Keralite culture shaped the personal identity of each parishioner. In her senior thesis work, *The Struggle for Identity Among Syro-Malabar Catholics*, Jaisy Joseph notes: “The social customs of the Malabar Christians emphasized a high regard for family, education, and morality.”¹⁶ These values play a prominent role in the lives of Kerala Catholics in India as well as the U.S., as many participants

noted in the interviews conducted for this study.¹⁷ Catholicism has heavily influenced the way of life of Syro Malabar Catholics in Kerala as evidenced in “culture,” or the shared social norms and practices of people in the southern region of India.¹⁸ In describing their spirituality, participants report a deep devotion to Mary, the Mother of God, a fervent prayer life, and a distinctively contemplative form of meditative prayer derived from the Eastern Christian spirituality of the Syro Malabar Church.

Generational differences are another important trend. All interview participants acknowledged that there was a gap between the first and second generation, caused mainly by a difference in cultures and a lack of communication.¹⁹ However, there was also a division within the second generation due to difference in age. Older members of this generation—children of immigrants who arrived in the U.S. in the 70’s or earlier—admitted to feeling overwhelmed by the pressure of adjusting to two competing cultures.²⁰ But sentiments differ amongst the younger members of the second generation. Children who grew up within an established Syro Malabar Church (officially recognized as a mission in Chicago in June 1985) have been more successful at balancing both cultures.²¹ Members of this group reported that the presence of the Church alleviated their social struggles.²² The Church provided them with a venue to communicate with other children who shared the same experiences.²³ Syro Malabar has also provided the two generations with a common spirituality.²⁴ Overall, the younger members of the second generation seem to be reaping the personal benefits of a Syro Malabar Church in the U.S.

Despite the younger parishioners’ positive sentiments, the future of the Syro Malabar Church in the U.S. remains uncertain. Although it has taken steps to enrich the lives of its members with the Syro Malabar faith as noted above, the second generation still struggles to understand the importance of maintaining the minority rite. The significance of a Syro Malabar Church in

9. Raymond Brady Williams, *Religions of Immigrants from India and Pakistan* (New York: Cambridge University Press, 1988).

10. Donald Attwater, *Eastern Catholic Worship* (New York: The Devin-Adair Company, 1945) p. 185.

11. Jaisy Joseph, *The Struggle for Identity Among Syro-Malabar Catholics* (U.S.A., 2009) p. 83

12. According to the scholar, Raymond Brady Williams: “The Second Vatican Council ‘opened the windows of the church’ and led to negotiations within the Indian Catholic Church that still continue and exert influence on immigrants in America.” Raymond Brady Williams, *Christian Pluralism in the United States: the Indian Immigrant Experience* (Great Britain: Cambridge University Press, 1996).

13. St. Thomas Syro Malabar, Inc., *St. Thomas Syro Malabar—Diocese*, www.stthomasdiocese.org/parishes, (2004).

14. As one participant noted, “It’s almost like a meal that is less filling when I go to a Catholic Church here in United States. I don’t identify with them. I can never identify with them.” Chicago Parishioner 29, in a personal interview, Bellwood, Illinois, October 2009.

15. One gentleman noted during his interview: “[...] the three pillars of the Syro Malabar Church [are]: Catholic by faith, Eastern by worship, and Indian by culture.” Chicago Parishioner 3, in a personal interview, Bellwood, Illinois, September 2009.

16. Jaisy Joseph, *The Struggle for Identity Among Syro-Malabar Catholics* (Dallas, Lulu Publications, 2009) p. 28.

17. For example, the topic of strong family values in the Syro Malabar community was discussed at length with Reverend Father Jos Kandathikudy, in a personal interview (Bronx, New York, July 2009).

18. One participant noted that these values derive from a devotional life found in the Syro Malabar Church: “It’s inherent in [this] culture that Jesus is the Word. That Jesus is the Way, the Truth and the Life. There is no question. There is no confusion.” Chicago Parishioner 19, in a personal interview, Bellwood, Illinois, September 2009.

19. It was noted in all 54 interviews that difference in culture or lack of communication, or both, create a gap between the two generations.

20. This distinction had been first made by Bronx, New York Parishioner 11.

21. Raymond Brady Williams, *Christian Pluralism in the United States: The Indian Immigrant Experience* (Great Britain: Cambridge University Press, 1996) p. 145.

22. One young parishioner explains: “I let [my parents] know what I want to do...as long as [my mother] knows who I’m with...if it’s like you guys [Syro Malabar youth]...she will have no problem because she knows that you’re all good.” Chicago Parishioner 13, in a personal interview (Bellwood, Illinois, September 2009).

23. According to one parishioner: “...the unity of all the kids of all the same ages...you feel more comfortable with your own people...” Chicago Parishioner 13, in a personal interview, Bellwood, Illinois, September 2009.

24. “For me, it has shortened the gap because me and my parents both enjoy living the faith. So although our ideologies may be different we can still talk about how awesome prayer meeting was.” Chicago Parishioner 18, in a personal interview, Bellwood, Illinois, September 2009.

the U.S. appears to resonate with most participants on a personal level. However, the role of the Syro Malabar rite in the Universal Catholic Church,²⁵ as a proponent of unity in diversity, has not yet been recognized by the majority of first generation Syro Malabar Catholics, let alone by the next generation that is expected to preserve the rite.

Thus, one question in the survey concerned the role of the Syro Malabar Church in the Universal Catholic Church. According to Msgr. Kuriakose, Syro Malabar, as a member of the twenty two independent sui iuris churches (i.e., churches governed “under their own law”), maintains a “relative autonomy.” In other words, the Syro Malabar Church, although distinctively Eastern, has the same faith mission as the Universal Catholic Church. Reverend Father Jos Kandathikudy, pastor of the St. Thomas Syro Malabar Church in the Bronx, New York, notes that the Universal Church should be likened to a communion in which one encounters a unity in diversity. He explains uniformity should not be equated with unity for the Catholic Church. As noted in *Lumen Gentium*, although there are a number of different traditions, all Catholics share the same faith.²⁶

This same faith allows all Catholics, Kerala Catholics included, to partake in the sacrament of Eucharist, a highly symbolic act of faith that simultaneously signifies participation in the Body of Christ and in universal Catholic communion.²⁷ Participants reported experiencing the fullness of the sacrament of Eucharist in the Syro Malabar Church in the U.S., adding that this fullness surpassed any inadequacy they felt in purely social or cultural encounters. The Syro Malabar Church of the U.S. thus plays an integral and transnational role in uniting through the Eucharist thousands of Indian immigrants with the global Catholic Church both in the U.S. and India. Therefore, once the authenticity and the vital contributions of the Eastern Church to Catholicism have been fully realized by Syro Malabar Catholics and other Catholic Christians alike, the Syro Malabar rite will serve as timely global example of how Catholic communion is only ever realized as a unity in diversity.²⁸

25. This topic was directed only to the Church officials and it came up spontaneously in the other interviews.

26. Pope Paul VI, *Dogmatic Constitution on the Church: Lumen Gentium*, www.vatican.va/archive/hist_councils/ii_vatican_council/documents/vat-ii_const_19641121_lumen-gentium_en.html (November 1964).

27. According to theologian William Cavanaugh: “Each eucharistic community is not merely a part of a whole[...] but a microcosm, a mini-cosmos in which the cosmic Christ is wholly present.

The closer one is attached to the particular community gathered around one particular altar, the more united one becomes to the universal.” William T. Cavanaugh, *Being Consumed: Economics and Christian Desire* (Cambridge: Eerdmans, 2008), p. 71.

28. According to Williams: “If the Catholic Church is able to fashion a model of relationship attentive to distinct rites [...] it will have the value of combining the strength of unity and the beauty of diversity.” Raymond Brady Williams, *Christian Pluralism in the United States: The Indian Immigrant Experience* (Great Britain: Cambridge University Press, 1996) pp. 264, 265.

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Fudo Myo-o

Vanessa Morales*

Abstract Images of the deity *Fudo Myo-o* were frequently created for worship by followers of Shingon Buddhism in Japan. The Shingon sect of Esoteric Buddhism, which was founded in the seventh century by Kobo Daishi relied on visual forms to convey its complex doctrines, making it popular among Buddhist art patrons. Sculptures of *Fudo Myo-o* demonstrate a shift in Buddhist thought from an emphasis on the laity attaining salvation to a focus on their resolution of immediate daily concerns. *Fudo Myo-o* came to be seen as the ultimate guardian at a time when Japan suffered from ongoing war, natural disasters, and epidemics.

A thirteenth century wooden sculpture at the Art Institute of Chicago, entitled *Fudo Myo-o* (acquisition number 1958.321, room 102), illustrates the proliferation and importance of images of Esoteric Buddhist deities in Japan during the Kamakura period (1185–1333), as does an early-13th century sculpture of *Fudo Myo-o* in the Mary Griggs Burke Collection of Japanese art at the Metropolitan Museum in New York.¹ Images of guardian kings or *myo-o* deities demonstrate the shift in Buddhist thought from an emphasis on the laity attaining salvation to a focus on their resolution of immediate daily concerns.

Since its introduction in Japan in the sixth century, Buddhism had been promoted by nobility as a great source of virtue. However, it did not take root in Japan until the seventh century. This is when the monk Kobo Daishi traveled to China, where he studied Shingon Esoteric Buddhism, and then returned to introduce the new version of the faith to Japan.² He relied largely on visual forms like sculpture, believing they would aid in simplifying Shingon's complex doctrines. These forms were thought to be so powerful that the mere sight of them would bring great immediate benefits.

The *Fudo* at the Art Institute of Chicago is a wooden sculpture with polychromy and gilt bronze accessories. It sits stiffly above a heavily stacked pedestal. The sculpture's massive bluish-black body, reflective of the Chinese Tang style, gives the deity an undeniably commanding presence. His stylized, deeply incised face, exposed fangs, fiercely raised eyebrows, and piercing, bulging eyes—one of which looks heavenward and the other directly

at the viewer—cast a series of dramatic shadows. The thin diaphanous garb that tightly hugs his voluptuous body, created through curved contours, amplifies his powerful presence. He clenches a rope in his large, firm fist and wears a gilded necklace decorated with a lotus flower motif. Fudo's sheer muscular force and aggressive stance attest to his supernatural power.³ The snail shell curls, elongated earlobes, and lotus flower signify that this is a holy figure. Fudo destroys evil and wickedness with the sword he holds in his left hand and captures those led astray from Buddhist teachings with the rope he holds in his right hand; in this way, he teaches the stubborn sentient beings.⁴

Like other art works created for Esoteric Buddhist practice, sculptures of Fudo were used as objects to aid prayer and meditation. The *Fudo Myo-o* in the Burke Collection conveys an effect of grotesque rage similar to that expressed in the Art Institute's sculpture. However, the figure in the Burke Collection is much more refined. Despite his broad shoulders and fierce facial expression, his body has a narrower waistline, his face is thinner, his arms defined, in contrast to the overall roundness and solid massiveness of the sculpture at the Art Institute. The addition of bracelets and the armbands contributes to a naturalistic idealization of the Burke Collection figure whose diaphanous robe is rendered with much more accuracy, revealing the elongated body underneath. The stance of the figure is no longer overwhelmingly intense. Instead, the delicate, relaxed hands holding the rope and sword remind the laity of Fudo's great power to conquer evil.⁵

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1. *Achala (Fudo Myo-o)* is illustrated in Denise Patry Leidy, *The Art of Buddhism: An Introduction to Its History and Meaning* (Boston and London: Shambhala Publications, 2008), figure 10.8.

2. Julia Meech, "A Painting of Daitoku from the Bigelow Collection," *Boston Museum of Fine Arts Bulletin* (1969): 18.

3. Takaaki Sawa, *Sculpture of Japan from the Fifth to Fifteenth Century* (New York: The Viking Press Inc., 1959), p. 27.

4. Hiromitsu Washizuka and Roger Goeppe, *Enlightenment Embodied: The Art of Japanese Buddhist Sculptor (7th–14th centuries)* (New York: Government of Japan Society Inc., 1997), p. 27.

5. Sawa, 28.

While some in earlier Japan learned and mastered the intricacies of Buddhist scripture and rituals, it is unlikely that many fully understood their profound meaning.⁶ Shingon Buddhism intentionally utilized impressive art to attract, enthrall, and educate the laity.⁷ With the aid of visual forms, like sculptures of Fudo, the complexity of the doctrines could be more succinctly expressed to a vast number of people in a relatively short time.

To activate the fierce Fudo's power, Shingon worshipers had to undergo severe rituals, such as standing under a plunging waterfall to purify their body and spirit or performing a number of austerities in darkened halls.⁸ The sense of the deity's presence in the flickering, candle-lit halls was emphasized by his grimacing face, turbulent drapery, and menacing weapons, creating an unequivocal psychological experience. The aura of a fierce, monumental deity made his presence even more profound and gave worshippers the feeling that the deity stood before them. This helped followers relate to an otherwise intimidating and aggressive divinity. The laity were encouraged to believe that the deity existed in their world. However, the promise of protection and genuine advantages in this life had perhaps the greatest appeal, further fueling the popularity of Fudo during the tenth and eleventh centuries.

Uncertainty and fear had historically plagued Japan and Kobo Daishi made the protection of a terrified country his number one priority. Royal patronage of Shingon Buddhism allowed it to flourish. Shingon Buddhism continued to appeal to the vulnerable in Japan through its emphasis on ritual and visual grandeur, quick salvation for the laity, and imperial endorsement.

Fudo's popularity spread and he became one of the main divinities worshipped in Japan. According to Takaaki Sawa, since the Esoteric doctrines offered followers the possibility of attaining buddhahood during this lifetime, their appeal was not limited to the wealthy but expanded rapidly to the masses both in the capital and the provinces. Eventually laity around the country came to worship Fudo in hopes of ensuring Japan's safety and prosperity. Fudo's role as the protector of Buddhist law or dharma was secondary once he became the guardian of Japan.⁹

In the thirteenth century, when the two sculptures of Fudo described above were made, violence, fear, and trepidation weighed on many Japanese citizens. The spiritual need to attain salvation, and ultimately enlightenment or buddhahood was replaced by even more immediate worries in a laity seeking solu-

tions to the problems that threatened their corporeal existence. In the previous century, the country had been ravaged by civil war. Then, in the thirteenth century, the Mongols repeatedly tried to invade Japan by sea, ending only when fierce storms and turbulent waters destroyed their ships and ultimately caused them to retreat. Epidemics and earthquakes brought further distress.¹⁰ Now more than ever the need for protection sparked interest in savior gods.

The military government established during the Kamakura period exalted martial virtues, further popularizing Fudo. This fearsome deity was worshipped as the patron of warriors, and his image often decorated samurai armor and swords. The rugged image of Fudo embodied qualities respected by the samurai, as he relentlessly defended the law of the dharma and loyally ward off evil, no matter how difficult or dangerous the situation. The immense and supernatural power of Fudo inspired the Japanese warrior to enter battle with sword in hand and Fudo as his protector.

The potential of Buddhism to unite society in pursuit of a common cause made it extremely attractive to warriors and the nobility. Shingon Buddhism thus became an ally of the ruling regime. Practicing Buddhism was said to endow the aristocracy with virtue and allow them to attain buddhahood in this lifetime. Promoting Esoteric Buddhism also promised them the accumulation of good karma. However, the promise of a united territory, along with a content and obedient people, was the real benefit of a faithful Buddhist population. As a result, Buddhist conduct became a paradigm for official state actions as well as everyday social behavior.¹¹ In fact, Shingon rituals were often held in the imperial palace to ensure the safety of the nation and the health of the emperor; many clergy members held court rank.¹²

Shingon's promotion of heroic masculinity in its rituals, the incorporation of austerities, and the benefits of worshipping Fudo appealed to valiant warriors, powerful aristocrats, and ascetics living in rural and mountainous areas. The rigorous devotion to Fudo by mountain ascetics was equated with the spiritual dedication of the historical Buddha. For the mountain ascetics, Fudo was a physical manifestation of unsurpassed control and strength who stays rooted to his mission without losing composure in the face of evil and wickedness. Not everyone can remain level-headed in the face of chaos.

6. Joseph M. Kitagawa, *The Buddhist Transformation in Japan, History of Religions 4* (Winter, 1965): 324.

7. Katharina Epprecht, ed., *Kannon: Divine Compassion, Early Buddhist Art from Japan* (Zurich: Museum of Reitbert, 2007), p. 29.

8. Sawa, p. 96

9. Felice Fischer, *Japanese Buddhist Art, Philadelphia Museum of Art Bulletin 87* (Winter, 1965): 45.

10. William Watson, *Sculpture of Japan from the Fifth to Fifteenth Century* (New York: The Viking Press Inc., 1959), p. 36.

11. Kitagawa, p. 28.

12. Meech, p. 31.

The remote, mountainous region where followers practiced Fudo rituals provided the ideal environment for the demanding and vigorous Shingon practices while offering followers a place of peace and harmony. Kobo Daishi himself believed that the mountains provided the most suitable environment for the kind of study and training needed for Shingon practice,¹³ one where concerns of war, epidemics, and natural disasters could be temporarily set aside. In addition, the intense concentration needed to cleanse the mind and spirit distracted followers from their immediate worldly troubles. The tranquil, secluded environments, the intricate, arduous rituals, and the psychologically stimulating sculptures provided many Shingon followers with the most immediate of rewards: peace (albeit temporary), spiritual enrichment, and a cathartic experience.

Later, in the modern period, Shingon succumbed to nationalism, militarism, and imperialism.¹⁴ Prayers came to be incorporated into daily government actions, stripping the sacredness from acts of devotion and converting them into a practical strategy for maintaining the prosperity of the modern state. Warriors, like Fudo, fought for a divine cause, the future of Japan, and military leaders alluded to the emperor as a supreme being. Buddhism used as the foundation for a military agenda made members of the armed forces more likely to sacrifice themselves for their country. In praying to Fudo for the safety of Japan, the average person could feel part of the war effort. The populace depended on the military to protect them from perils of war, and the military depended on the prayers of the people to ensure victory for the state.¹⁵ This symbiotic relationship of religiosity and the fate of the greater society strengthened a common national identity considered crucial for survival during turbulent periods. Once war and fear had subsided, the Esoteric notion of paradise on earth was nurtured in the worship of Fudo, benefitting those who believed in him.

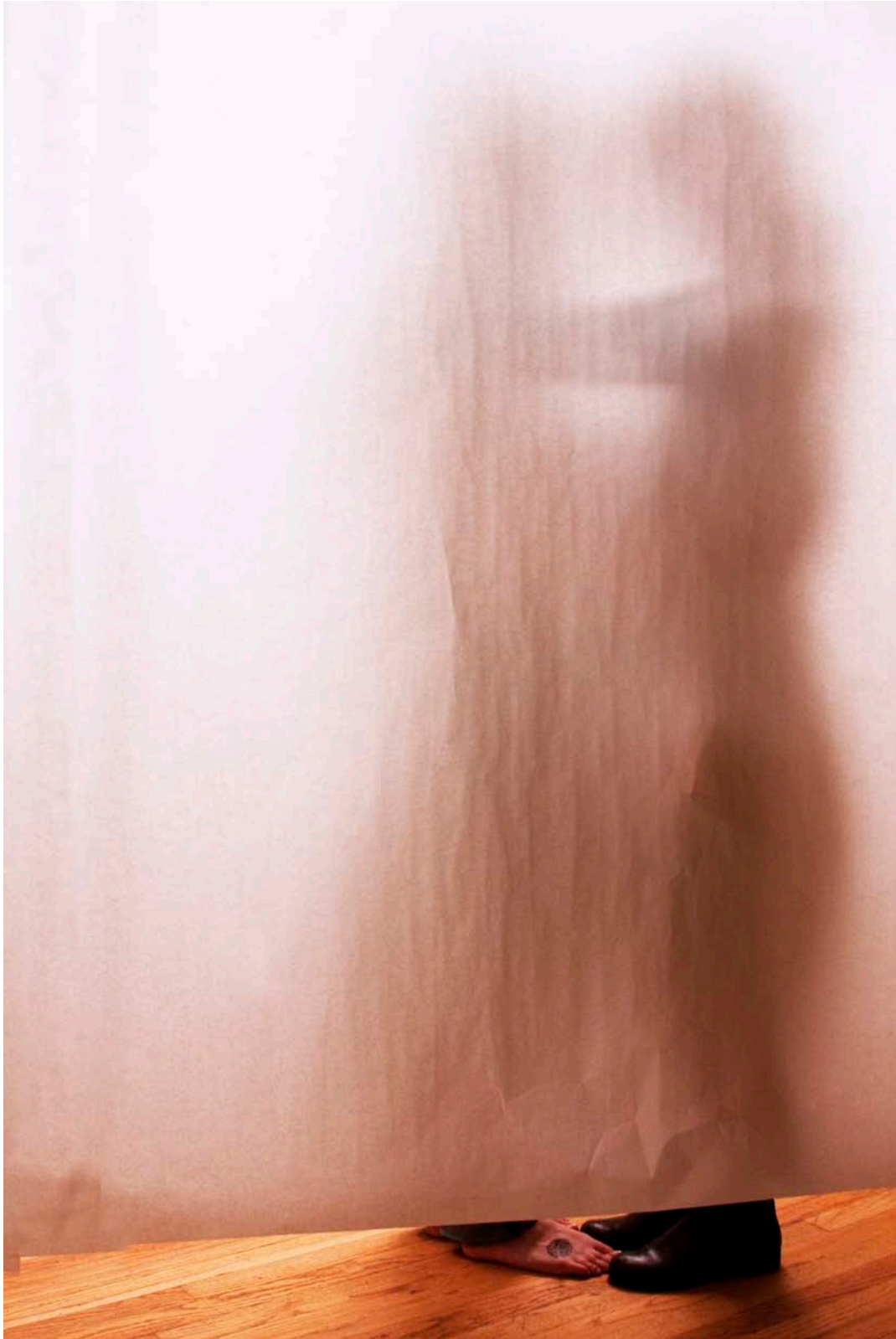
The grandeur of the rituals, the supposedly magical practices, and Fudo's power to grant wishes for good health, prosperity, and other worldly things had an undeniable appeal. Believing that Shingon rites controlled the forces of the cosmos, many people appealed to Fudo to ward off evil spirits and bring them supernatural help to deal with their worldly concerns. Lay people did not always worship the deity to aid them in their journey to enlightenment, but often sought his help to fulfill their present desires for success, power, fame, and wealth, to help a friend or to defeat an enemy. Early on Fudo promised protection for those seeking salvation; later on he became no less than the guardian of the Japanese nation.

13. Sawa, p. 113.

14. Kitagawa, p. 328.

15. John M. Rosenfield, The Sedgwick Statue of the Infant Shotoku Taishi, *Archives of Asian Art* 22 (1968/1969): 56-79.

16. Blanche W. Magurn, Daitoku Myo-o, a Japanese Buddhist Deity, *Bulletin of the Fogg Art Museum* 10 (Nov., 1942): 17.



Amanda Grupp
In the Shadows
Digital Photography

Guanyin and Shukongo-jin: Deities in the Buddhist Pantheon

Adrianna Teolis*

Abstract Although originating in India, Buddhism eventually spread east across Asia, adapting to native faiths as it reached new destinations. The faith, as well as its art, developed according to each country's culture and politics. This paper examines such changes in the Buddhist art of China and Japan. Focusing on the 12th century sculptures of *Guanyin* in China and *Shukongo-jin* in Japan, the essay shows the adaptations that Buddhism underwent due to specific circumstances in each country. Stylistic analysis of these artistic works shows variations of Buddhist art as it developed separately in China and Japan in the twelfth century.

Representations of the figures of *Guanyin* (Song Dynasty, China, 12th century, sculpture in polychromed wood) and *Shukongo-jin* (Kamakura period, Japan, 12th century, sculpture in polychromed wood) reveal Buddhism's changing emphasis as it developed in East Asia. The feminine characteristics of *Guanyin*, with its relaxed pose, contrast with the masculine characteristics of *Shukongo-jin*, which has a muscular, aggressive pose as reflected in its angular shapes and threatening effect. As Buddhism developed, it not only incorporated new figures as deities, but also affected people's conceptions of what it meant to be divine. Although created at the same time, *Guanyin* and *Shukongo-jin* demonstrate the changes that occur within Buddhism as it develops separately in China and Japan. I will show how these stylistic changes reflect the religious and political background of artistic works.

Guanyin

In 1127, the Jurchen people from northeast Asia invaded the Song Dynasty, founding their own capital in the north, and forcing the Song court to reestablish itself in the south. It was during such periods of instability that Buddhism flourished. In previous centuries, the acceptance of Buddhist art had been difficult in China because Buddhism was considered foreign and unable to provide a solution to its political problems. Its adaptability enabled Buddhism to merge with existing religions of Confucianism, which introduced ancestor worship, and Taoism, which provided a pantheon of deities. However, once they were able to translate their native faith into Buddhist traditions, their artistic work developed with sophisticated realism into human representation that Buddhism had carried with it.

Not only did new sections of Buddhism emerge from these cultural interactions, but it was also modified to fit the native worldviews. The Chinese had developed their own concepts of divine beings that reflected their native beliefs. Taoism, for example, focused on the human relationship with the natural world. The flow of energy through nature is a popular theme in Taoist artwork and a concept that was passed on to Buddhist art as well. Some newly emerged Buddhist sects that developed in China, such as Chan, incorporated Taoist notions. Chan followers were expected to devote themselves to meditation, no longer use icons for worship, and to rely upon individual effort rather than total devotion. Although icon worship had diminished, attention had been drawn toward real people, such as patriarchs and *luohan* who had reached nirvana in their lifetimes. Imagery focused on these enlightened individuals and relates to earlier Buddhist dependence on savior beings.

Although the exact origin of *Guanyin* is debated, it is believed to have been introduced to China along with Mahayana Buddhism in the fourth and fifth centuries. Buddhism became the rival of the traditional Taoist faith; however, it came to be accepted as it changed Taoist deities to better suit the emerging religion. Knowing this, it is possible that *Guanyin* was a Buddhist transformation of a Taoist deity. In China, the role of *Guanyin* shifted from a guide escorting souls to Paradise to the savior of the distressed. The sculpture of *Guanyin* is represented in a *lalitasana* pose in a seated, languid posture, with the right hand resting upon its raised knee, suggesting royal confidence and imperial power. It was sculpted during the Song dynasty when Buddhist art became highly naturalistic, being influenced by Taoism. Images of the bodhisattvas also became more noticeably feminine. The Guanyin, who appears as royalty with an elaborate crown and withdrawn expression, must have been commissioned by a

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wealthy patron. It is larger than life-size, making the deity more accessible to the viewer. The scale can be interpreted as an attempt to popularize Buddhism and make it available to all classes.

Guanyin serves to aid the suffering humans struggling to achieve enlightenment, just as a bodhisattva mediates between heaven and earth. The sculpture *Guanyin's* soft hands express a sense of compassion and tenderness that this deity emits. His serene facial expression and partial smile reflect his kind attitude towards the suffering world. The power and divinity of the bodhisattva are depicted through his bodily and facial expressions, as well as the adornment that indicates his physical location. In China, *Guanyin* is conceptualized living on an island in the Eastern seas, which is why he is surrounded by stylized waves. Although depicted in human form, the *Guanyin* remains divine and apart from the earthly realm. This is manifested by his foot, which rests on a lotus flower resting midway between the earthly and heavenly realms. A common symbol in Buddhist art, the lotus depicts the progression of one's soul as it emerges from muddy to grow into a beautiful flower. In this sculpture, the lotus symbolizes not only the path for Buddhist followers, but also demonstrates *Guanyin's* role as a mediator between heaven and earth, the muddy and the beautiful. This notion of divine beings residing in the Eastern seas evolved from native religious beliefs and expresses the adaptability of Buddhism.

While it was initially difficult for the Chinese to recognize Buddhist divinities, the corporeality of *Guanyin* is significant. The heavy flow of garments over the figure's body identifies *Guanyin's* character and shows his corporeality, revealing a divine figure still human in form. The manifestation of the dualistic figure is important: his human characteristics relate his divinity to the earthly world. As a bodhisattva, he has reached the point of enlightenment, yet has refused it in order to stay in the earthly realm to help others achieve the same goal. Thus, he remains simultaneously human and divine. Bodhisattvas, thus, have a special significance in Buddhism because they belong to both the godly and human realms. Besides depicting his divinity, the garment also has an active dimension. The bodhisattva of compassion and mercy actively reaches out to the human world to help ending our suffering. Depictions of bodhisattvas, while worshipped, were intended to exhibit ontological dualism, as opposed to the psychological aims of Buddha images. Although he waits in a relaxed pose, the flow of *Guanyin's* garments indicate his active role in saving the unenlightened in Buddhism. *Guanyin* is expected to physically affect the earthly realm, literally reaching out to those in need.

Shukongo-jin

In 12th century Japan, on the other hand, a warrior group called the samurai, who served a Shogun, the head of samurai, moved the capital to Kamakura in 1185 and formed a new government. It was during a period of warrior control that threatening and ferocious art such as *Shukongo-jin* was created. The native Shinto religion tends to focus on the powers of nature gods, or *kami*, inhabiting various natural objects, such as wind and rain. After its introduction to Japan in the 6th century, Buddhism had evolved to coexist alongside Shinto. Eventually, Buddhists adopted the Shinto gods into their own faith, seeing the *kami* as manifestations of the Buddha. The political situation affected the art and some gods became more aggressive-looking. Using humor, caricature, and realism, artists were able to appeal to the masses and market Buddhism as a faith for people of all classes.

Similar to the Song period in China, the Kamakura period in Japan depicts figures in the human sphere, making realism most important. Icons were created for worship, but sculpture could draw the viewer into a physical relationship with the object. With divine images appearing as humans, practitioners no longer worshipped the image as a mere icon but were encouraged to have a human relationship with the god. Images in the Kamakura period tend to depict the physical interaction between divinities and humans by having the figure descend into the viewer's space. The religious figures assume more dynamic self-contained static poses that seem to break the space barrier between icon and worshipper. Threatening images were used to manipulate people into leading good lives, showing them the consequences of infidelity, such as that of the *Shukongo-jin*.

Esoteric Buddhism, popular in Japan during the Heian period (794-1185), emphasized a pantheon of deities. The Buddhas are conceptualized in three forms: as bodhisattva, representing spirit; as vajra, representing wisdom or graciousness; and as guardian kings (*myoo*), representing Buddha's power against evil. *Myoo* are represented with fierce poses and angry expressions to help worshippers visualize their power to vanquish demons. Unlike *Guanyin*, to whom people pray for support, the *Shukongo-jin* is an active figure, able to influence those who do not seek his guidance. As a Buddhist guardian king, he has the power to convince the reluctant to accept Buddhist teachings. He is also able to physically protect them from ignorance, that is, the enemy of wisdom and the realization of enlightenment in Buddhist teaching. Because Buddhists believe that Dharma, which is commonly defined as the teachings of the Buddha or Buddhist Law, is constantly in danger of assault, worshippers require a threatening figure to protect them. A well-armed deity is just as necessary as one of compassion and consolation.

Artistically, the Kamakura period developed a sense of heightened realism, placing a new emphasis on a naturalistic rendering of pose, musculature, and drapery. The Kamakura artists favored intense and expressive scenes of demons. They were able to create images that radiated power and majesty. The Myoo typically hold weapons, such as the vajra to defend Dharma, or the Buddhist Law. The vajra is a stylized thunderbolt, a theme and image commonly found in Esoteric Buddhism, which symbolizes the power of wisdom and to cut through ignorance, the source of all suffering. Although the *Shukongo-jin* is physically smaller than the *Guanyin*, his threatening pose is overbearing. His facial expression alone can conjure up fear. Probably intended to be placed on a higher platform, the *Shukongo-jin* stares angrily downward at his enemies. His brow is furrowed with anger and his nose crinkled, causing his ferocious teeth to show in an almost beast-like way. His powerful face, full of aggressive emotion, is a drastic contrast to the serene expression of the *Guanyin*. Another striking difference is the musculature of the body. The *Shukongo-jin* stands with all his massive muscles flexed, ready for attack, whereas the body of the *Guanyin* remains relaxed and at ease.

These figures could easily be understood as opposites: one as deity, one as demon; however, both are worshipped as active figures within the Buddhist pantheon. This shared trait of *Guanyin* and *Shukongo-jin*, contrasting typical expressions of Buddha images, is also expressed visually through the poses of the sculptures. *Shukongo-jin* stares out aggressively, unlike a typical Buddha image with eyes looking inward in a state of meditation. His hand is raised with a weapon and his muscles are flexed for potential action. The pose of the *Guanyin*, while not as active as the *Shukongo-jin*, also differs from the typical symmetrical and vertical pose of the Buddha. He sits asymmetrically, almost reclining onto his left arm, making him appear a bit more dynamic and realistic.

The *Guanyin* and *Shukongo-jin* were made in countries where Buddhism had been introduced centuries earlier as a foreign faith. China and Japan were both dealing with political turmoil when they incorporated Buddhism, modifying it to fit into their preexisting worldviews. Those modifications altered the faith and the accompanying religious art. Although the formal characteristics of these works vary drastically as a result of specific cultural and political forces, the Buddhist concept of active assistance from deities remains consistent, as seen in *Guanyin* and *Shukongo-jin*.

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Re-Presenting Feminist Art: Macena Barton (1901-1986) and Her Representations

Jamie Shaw*

Abstract Macena Alberta Barton (1901-1986), a Chicago modernist painter, has unfortunately long been forgotten, although she and her contemporaries significantly contributed to art history and feminist art historical discourses. Barton and her colleagues implemented feminist devices in their art prior to the articulation of feminist art as a category; they nevertheless realized a feminist agenda through paint and creative alliances. This essay argues for a restructuring of feminist art, particularly its starting date of 1970, which would allow artists like Barton who practiced in the early twentieth century to be recognized for their influence on later feminist organizations.

Macena Alberta Barton (1901-1986), a Chicago modernist painter, has been erroneously¹ labeled in contemporary texts as an “unconventional feminist [who] painted self-portraits in many exotic guises, portraits of her friends and of notables..., some startling nudes, and a series of strange symbolist/surrealist works with floating heads and flying saucers.”² Indeed, Barton was an independent thinker and artist: as a German critic once noted, “The first impression [of her] is that conventionality gives her a pain.”³ Certainly Barton resisted the hegemonic norms of the early twentieth century. She is most noted for her portraiture⁴ composed before World War II,⁵ although she worked into the 1980s. Her individualism and style brought her a myriad of awards and membership in various artistic organizations. Although her credibility as an artist is solid, she has disappeared from both mainstream art history and contemporary feminist art historical discourses. Research on Barton and her contemporaries demands a re-presentation of feminist art and its criteria, including its starting date of 1970. It will be argued that throughout her career, Barton implemented feminist tactics; this essay attempts to broaden the scope of feminist art and, inexorably, art history in general, through an examination of Barton’s portraits, her self-representations, and her role in creative alliances.

Contemporary critics have labeled Barton a feminist; however, research finds tensions in current definitions of feminist art. Consider Norma Broude and Mary D. Garrard’s introduction to their anthology, *The Power of Feminist Art: The American Movement of the 1970s, History and Impact*:

What is feminist art? In the early 1970s, artists, critics, and historians who were part of the feminist movement believed that like the women’s movement itself, art made by feminist

*women represented a radical new beginning, Part Two in the history of that Western culture to complement the largely masculine history that would now become Part One.*⁶

This definition is helpful in several ways. First, it illuminates the very constricting timeframe (starting in the 1970s) in most definitions of feminist art. It elucidates the shortcomings of the traditional binary thought process found within Western historiography. This polemic has only two parts: in and male, or out and female.⁷ Although feminist art has incorporated the traditionally marginalized, within this organized category there still appear to be vast numbers of unrecognized artists, partly due to the limitations of this framework. Artist and theorist Mary Kelly resists this dichotomy by arguing for a different structure: “...perhaps we shouldn’t maintain this formulation ‘feminist art,’ because an ideology doesn’t constitute a style. Rather, I would say ‘art informed by feminism.’”⁸ Among other things,⁹ “Art informed by feminism” breaks down stereotypes associated with feminist art and allows the boundaries of a perceived stable category to collapse and become permeable. This permits artwork to be both informed by feminism and more mainstream practices, an appropriate position for an anomalous artist like Barton.

Barton constantly defied the imposition of labeling and constraints on her work, and it would therefore be unfair to simply call her a feminist artist. In a number of Barton’s early works she placed what were called auras around figures. Art critic C.J. Bullett explains:

Her sense of ‘ornament’ has resulted in the famous ‘auras’ that have mystified Chicago for three or four years. Around her portraits of both men and women, sinners as well as saints, she has been painting haloes of various colors—only one color, however, for each individual. It’s a shame to explode a theory rapidly approaching a legend. But the truth

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is, she has only appropriated a device common with the 'old masters,' and bent it to her own uses. The old painters were in the habit of separating their sitters from the background by a thin line of color that helped decidedly in the modeling. Miss Barton has taken the line, widened it, and, by drawing attention to it, used it for the purpose of ornament—very effectively.¹⁰

According to Bulliet, Barton used the old masters' (read, masculine) tools, but manipulated these devices for her own purposes. In this sense, she became her own master. Barton strategically subverted the masters' tools in order to challenge the assumption that women artists were deficient. She applied auras to her figures between 1932 and 1935,¹¹ but stopped shortly after being praised for doing so.¹² It seems that Barton resisted any sort of classification, particularly those placed upon her. It is important to note, however, that while she resisted categorization, she wanted to be acknowledged as a serious painter. This demanded accommodating the masculine tradition to some extent, and it appears she did so while simultaneously implementing feminist devices. Her art was informed by feminism and evident in her self-portraiture. Describing her self-representational work, Irwin St. John Tucker notes:

...peculiar expression[s are found on] the faces of her female subjects. It is not meanness that you see; it is the intent eye of the artisan at work...She cannot paint herself laughing; it can't be done. If you will try it once, you will see that if you laugh you cannot concentrate your attention enough to paint your own smile.¹³

This article was not intended to condemn Barton, but either way, it seems she was less than thrilled by this critic's assertion. In response, Barton painted *Macena Laughs* (ca. 1934).¹⁴ Bulliet comments:

Macena Barton has painted herself laughing so infectiously that the glummost spectator standing before the picture must feel his own face breaking into grin. Frans Hals could do that—Frans Hals and who else? Nobody that I can think of at present...Frans Hals, Macena Barton, and who else?¹⁵

Barton vehemently resisted classification by her male critics. To mark her a feminist artist would ignore her own resistance to labels and disregard her agency. Rather than ignore her idiosyncracies, it is more accurate to consider her artwork as informed by feminist principles, as several examples will illustrate.

Barton deliberately chose to represent her colleagues in portraiture that can be read as a feminist intervention. Her contemporaries include Gertrude Abercrombie (1909-1977), Julia Thecla (1896-1973), and Fritzzi Brod (1900-1952).¹⁶ She pictured a number of them in paint and at least Brod's,¹⁷ Thecla's,¹⁸ and Abercrombie's¹⁹ portraits are recorded.²⁰ Barton depicted each artist in a traditional manner; all are portrayed from the waist up, in their own

canvases.²¹ It is not a coincidence that Barton chose to venerate her female contemporaries. She could have chosen any number of subjects to paint: male artists, still lifes, and so on. Through title and subject Barton strategically drew attention to them—in other words, promoted them.²²

Evidence suggests that Barton and her contemporaries promoted each other's work collectively. In 1937, the pamphlet for the First Annual Women Artists' Salon in Chicago appeared.²³ At this time, Barton was under contract with the Illinois Art Project, part of the federal Works Progress Administration, but was also seeking membership in the Salon because of the limited opportunities available to women artists during this time.²⁴ Professor Joanna Gardner-Huggett points out, "...while women's artists organizations like these did not challenge patriarchal governance structures, they did provide support, exhibition space, instruction and models—significant steps toward greater participation of women in the art world."²⁵ The constitution of the Women Artists' Salon pointedly stated: "The object of this society shall be to hold Exhibitions of original works of Art by women artists; and to promote the interests of Art and Artists in general..."²⁶ Barton and her associates endorsed one another's artwork in order to withstand the patriarchal practices within the art world and, consequently, they promoted social change. Unfortunately, as Gardner-Huggett points out, "...most of the archival material related to the Women Artists' Salon has disappeared..."²⁷ Even so, it is crucial to note that "The Salon prefigures women artists' cooperatives that would form in the early 1970s in Chicago, such as Artemisia and A.R.C., driven by the ideology and activism of second-wave feminism..."²⁸ Here, it is imperative to include Barton and the Salon within art history. In addition to the women's salon, Barton was highly involved in the Chicago No-Jury Society of Artists, whose object was, "...to hold annual exhibitions of art without jury and other objects of democratic ideals to promote the artist and art."²⁹ If the women's Salon was the antithesis of the male art world, then the synthesis seemed to be the No-Jury Society, as it worked (in part) to break down hierarchies. By organizing such societies, it is clear that these artists did not assume a passive role in their careers, again demonstrating what I can only read as feminist activism.

Moreover, Barton and her contemporaries fought against the patriarchal limitations placed upon their own self-representations. Critic Elenor Jewett notes:

[Barton] feels proportion and composition and the character of things on a big scale. This is the more extraordinary inasmuch as she, in her own person, is delicate, petite, exquisite. Her self-portraits are amusing jokes. In them she figures largely and breezily. Possibly a Freudian complex flowering, but we are delighted with the fruit. These self-portraits are among her ablest and most dramatic.³⁰

Unlike Jewett, I do not believe Barton's representational selves are merely "amusing jokes", but instead political statements regarding the negotiations imposed upon women artists, like Barton, applying feminist tactics at this time like female masquerade. Art historian Whitney Chadwick has argued, "Masking, masquerade, and performance have all proved crucial for the production of feminine subjectivity through active agency."³¹ Barton embodied a variety of identities in her portraiture despite being of "...Michigan birth and English descent..."³² Around 1930 she painted *Macena With a Turban*³³ and a self-portrait "...in [the] style of Queen Nofretete [sic] of Egypt."³⁴ For *Wine*³⁵ and *Self-Portrait* (ca. 1928),³⁶ she adopts two additional identities. In *Wine*, her hair is slicked back, signifying masculinity, in contrast to the 1928 self-portrait where her hair is severely parted down the middle with feminine buns on each side. A later self-portrait from 1974³⁷ shows her in a sombrero as an apparently young woman with red hair, although at this point she would have been in her early 70s. In *Last Years Bird's Nest* (1945),³⁸ Barton depicts herself solemnly with dark hair and clothing. By adopting performative identities, Barton subverted patriarchal limitations.

It is important to situate *Last Years Bird's Nest* within Barton's own narrative in addition to a sociohistorical framework. Interestingly, Barton fashioned her gender somewhat ambiguously for this painting.³⁹ She adorns her womanly figure with a masculinized suit. The wilting top hat and suit coat, both in muted shades of brown, contribute to a less-than feminine appearance. She holds an empty bird's nest on a stick, the way a bridesmaid would carry a bouquet for a wedding portrait. No detail appears to be too small for Barton: even the suit buttons are found on the right, where they would traditionally be found in masculine attire. The masculinely gendered suit conceivably points to the identity "artist" which would render her unable to assume the role of housewife and mother, the idealized and propagandized role for women at this time. Barton was unmarried, childless, and in her early 40s when she created this portrait (although she would eventually marry in the early 1950s).⁴⁰ Gardner-Huggett argues that Barton's contemporary "...Thecla...rejected the expectations of her upbringing by refusing to marry and have a family. Instead she committed herself to a life as an artist, which...was still considered an inappropriate profession for women."⁴¹ In 1945, Barton's nest was empty. Perhaps this portrait allowed Barton to show the obligatory choice made in order for her to assume an artistic identity. Every role Barton embodies in the canvas is performative to some extent. It appears Barton was analyzing cultural constructions in her self-representations.

Judith Butler says all gender is performative, but ultimately describes this performance as a compulsory choice.⁴² Barton's exaggerated guises suggest an understanding of gender (culture) as a performative discourse. Like Barton, Thecla also used costume as a subversive tool. Thecla often represented herself in hyper femi-

nine attire both physically and artistically.⁴³ Barton adopted hyper feminine clothing in person, but in contrast to Thecla, embodied new identities in the paint.⁴⁴ Gardner-Huggett writes that Thecla was "...aware of the gendered narrative imposed upon [her] and acted against it" through the use of female masquerade.⁴⁵ Furthermore, Thecla used "...excessive femininity as a way to assuage [male] fears of the assertive female artist."⁴⁶ Joan Riviere argues in her psychoanalytic essay from 1929, "Womanliness as Masquerade,"⁴⁷ that, "Womanliness...could be assumed and worn as a mask, both to hide the possession of masculinity and to avert the reprisals expected if she was found to possess it..."⁴⁸ Barton perhaps acted out preemptory femininity in daily life in order to negotiate the tensions inevitably found in professional artistry; thus her opportunity to criticize constructions of gender and culture was in paint.

Barton challenged societal norms in her intimate relationships as well. She displays overt defiance in *Portrait of C. J. Bulliet* (1932),⁴⁹ the married art critic with whom Barton had an intimate and public relationship that lasted for more than 10 years.⁵⁰ Barton's portrait of Bulliet was first presented in the Annual Exhibition of American Paintings and Sculpture at the Art Institute of Chicago⁵¹ and was meant to commemorate their relationship in the public sphere.⁵² On the left side of the canvas, over Bulliet's shoulder a self-portrait of Barton calls attention to their relationship.⁵³ It should be noted that her self-representation is placed higher on the wall than the painting of the Madonna and Child, which appears over Bulliet's opposite shoulder. Barton defiantly critiques the social standard by elevating herself above the Christian icon. Christ and Mary look only at each other, but both Bulliet and Barton stare directly at the viewer, challenging any shame the spectator might want to impose on them for their affair. This entire portrait may be viewed as a political statement in defense of Barton's philosophy in regards to religion as well as her insistence on sexual freedom.

Notwithstanding her scandalously intriguing biography, Barton should not be considered merely rebellious, considering the contexts of her art and activism. Her portraiture and membership in artistic alliances promoted social change and in her self-portraits she commented on larger issues, such as the cultural constructions through masquerade. She promoted her female contemporaries in representational form. Finally, she encouraged solidarity among women artists during her lifetime as an act of feminist resistance through the Women Artists' Salon. My research shows that Barton and her colleagues were implementing feminist tactics in art prior to World War II, long before the category of feminist art as originating in the 1970s. Their artistic practices merit not only further investigation, but a deconstruction of limitations that are often placed on art informed by feminism.

1. I argue throughout this essay that Barton has been mistakenly labeled a feminist. As of yet, I am still unable to find any documentation in which Barton self-identifies as a feminist.
2. Sue Ann Kendall, "Midwest," in "Regional Reports," *Archives of American Art Journal*, Vol. 27, No. 1 (1987), 36.
3. Translation of newspaper article from "Sonntagpost," from Feb. 21, 1932, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Archives of American Art, Smithsonian Institution, Washington, DC.
4. Although Barton painted portraiture, a traditional genre, she did so in a Vincent Van Gogh-like style. Her portraits are detached from a realistic world, but somehow simultaneously highly realistic. She maintained a relatively consistent style in portraiture throughout the 60 years she practiced by implementing a traditional approach in a modernist way. She depicts her subjects and herself, usually from the waist up, only using oils on canvas. Her color scheme is always bright and sharp, but her representations are anything but conservative.
5. Susan S. Weinginer, "Macena Barton," *Chicago Modern, 1893-1945: Pursuit of the New*, ed. Elizabeth Kennedy, (Chicago: U of C Press, 2004), 89.
6. Norma Broude and Mary D. Garrad, "Introduction: Feminism and Art in the Twentieth Century," Norma Broude and Mary D. Garrad, eds., *The Power of Feminist Art: The American Movement of the 1970s, History and Impact*, (New York: Harry N. Abrams, 1994), 10.
7. The dichotomous ideology that surrounds most Western art history unfortunately extends to feminist art as well as most other disciplines.
8. Silvia Kolbowski and others, "A Conversation of Recent Feminist Art Practices," October, Vol. 71, feminist issues (Winter, 1995), 50-52.
9. Art informed by feminism allows for an imperative fluidity to what has become a stable category. It eliminates artistic typecasting and a polemic discourse by resisting the compartmentalization of artwork into only one camp. This distinction permits artwork to be both informed by feminism and also belong to more mainstream practices, an appropriately pivotal position for artists like Barton. With Kelly's framework, a portrait can be both informed by feminism, belong to modernism, and/or be considered traditional. Art informed by feminism does not necessarily have to "look" feminist (which has too often meant "in your face" vulva imagery or an obvious rejection of patriarchal practices) for it to be in dialogue with feminist ideology, nor does the artist have to "be" a "feminist" in order for her to be welcomed into this discourse. Art informed by feminism further mitigates our current dichotomous thought processes because it does not stipulate a beginning or an end; this kind of art rests on a continuum. To put it more simply, what we now consider feminist art did not exist when Barton was painting the majority of her works, as this term had not yet entered art historical discussions. Nevertheless, time and language barriers should not detract from the feminist interventions that Barton and her contemporaries employed. Art informed by feminism resists the label of feminist artist, but also recognizes their art and activism as informed by feminism. It is crucial, then, to negotiate Barton's work with time and language by describing it as art informed by feminism.
10. C.J. Bulliet, "Of Macena Barton and Her 'Auras,'" *The Chicago Daily News*, Saturday, Date unknown,
11. Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 705, Archives of American Art, Smithsonian Institution, Washington, DC.
12. Weinginer, "Macena Barton," 89.
13. Andrew Patner, "Macena Barton; Robert Henry Fine Art; Chicago," *New Art Examiner*, Vol. 22, (Mar. 1, 1995), 40.
14. Irwin St. John Tucker, Unknown newspaper cutting, Date unknown, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 645, Archives of American Art, Smithsonian Institution, Washington, DC.
15. Although the location of this painting is unknown, a reproduction was found in C.J. Bulliet, "Macena Laughs," *The Chicago Daily News*, Sat., Sept. 15, 1934, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 708, Archives of American Art, Smithsonian Institution, Washington, DC.
16. C.J. Bulliet, "Macena Laughs," *The Chicago Daily News*, Sat., Sept. 15, 1934, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 708, Archives of American Art, Smithsonian Institution, Washington, DC.
17. Sue Taylor, "Lakeshore Modernists," *Art in America*, Vol. 92, Issue 10, (Nov. 2004), 75.
18. C.J. Bulliet, Unknown newspaper cutting, Date unknown, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 673, Archives of American Art, Smithsonian Institution, Washington, DC.
19. Adeline Lobdell Pynchon, "Dinner Table Art," Sat., June 11, 1938, Newspaper cutting from Macena Barton Archive.
20. Tom Vickerman, Unknown newspaper cutting, Date unknown, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 673, Archives of American Art, Smithsonian Institution, Washington, DC.
21. Bulliet, "Of Macena Barton and Her 'Auras.'" 89
22. This suggests that Barton acknowledges every individual's particular agencies. Rather than compose a group portrait of her contemporaries, each is given their own space within the frame.
23. Through a clever use of titling, Barton supported women's artistry and avoided their objectification by granting these artists agency. All of her subjects' identities are kept in tact. She did not fragment these women into the category of woman, thereby avoiding stereotypes. This was achieved by titling her representations of these artists according to the subject's name. She used Brod's, Thecla's, and Abercrobie's names as the titles of their portraits, rather than an easily stereotyped and objective title, such as "woman artist."
24. Joanna Gardner-Huggett, Julia Thecla: Undiscovered Worlds, (Chicago: DePaul University Museum, 2006), 14.
25. Ibid., 14. For a nuanced discussion of the negotiations and acts of resistance women artists employed while working for the WPA see: Kimm Carlton-Smith, "A New Deal for Women: Women Artists and the Federal Art Project, 1935-1939, Ph.D. diss., Rutgers The State University of New Jersey, 1990, 34-62
26. Ibid., 14-15.
27. Constitution of The Women Artists' Salon of Chicago, Inc., Nov 15, 1939, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 602, Archives of American Art, Smithsonian Institution, Washington, D.C
28. Gardner-Huggett, Julia Thecla: Undiscovered Worlds, 15.
29. Ibid.
30. "Certificate from State of Illinois, Secretary of State for the organization of Chicago No-Jury Society of Artists," Aug 3rd, 1938, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Archives of American Art, Smithsonian Institution, Washington, DC.
31. Eleanor Jewett, "Works of Macena Barton on View," *Chicago Daily Tribune*, May 24, 1931, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 647, Archives of American Art, Smithsonian Institution, Washington, DC
32. Whitney Chadwick, "An Infinite Play of Empty Mirrors: Women, Surrealism, and Self-Representation," in *Mirror Images: Women, Surrealism, and Self-Representation*, Whitney Chadwick, ed., (Cambridge: MIT Press, 1998), 22.
33. Bulliet, "Of Macena Barton and Her 'Auras.'" 89
34. C.J. Bulliet, "[Chicago's] Portrait Show," Sun., [New York Times, March 13, 1932, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 658, Archives of American Art, Smithsonian Institution, Washington, D.C The whereabouts of the original Macena with a Turban is unknown; however, she did reproduce this self-representation in Portrait of C.J. Bulliet (1932), which is now in the collection of Mr. and Mrs. Harlan J. Berk, Chicago, Illinois.
35. The location of this painting is unknown. It was discussed in C.J. Bulliet, "Paintings in Lively Group Show What Jury 'Missed,'" *The Chicago Daily News*, Tues., Nov. 15, 1932, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 685, Archives of American Art, Smithsonian Institution, Washington, DC.
36. A reproduction of this piece was found in C.J. Bulliet, "Our Leading Modernist," *The Chicago Daily News*, Sat., Feb., year unknown, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 710, Archives of American Art, Smithsonian Institution, Washington, DC.
37. This date is approximate and based on an untitled newspaper clipping. A reproduction of this image can be found in Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Washington DC., Archives of American Art, Smithsonian, which reveals the painting was held in, "... Barton's one-man show at the Art Institute". Her one-person show was held at the Art Institute in 1928.
38. Self-Portrait, (c. 1974), Collection of Mr. and Mrs. Harlan J. Berk. Chicago, Illinois.
39. Collection of Mr. and Mrs. Harlan J. Berk. Chicago, Illinois.
40. This merits further investigation as only preliminary work has been done on dress of the 1940s; however, empirical evidence suggests the outfit illustrates an evasive identity.
41. Death Certificate of Francis McNeilan, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Archives of American Art, Smithsonian Institution, Washington, DC.
42. Joanna Gardner-Huggett, "Redefining Self-Representation: Julia Thecla's Full Moon (1945)," *Women's History Review*, Vol. 18, No. 4, Sep. 2009, 534.
43. Judith Butler, "Imitation and Gender Insubordination," in *Lesbian and Gay Studies Reader*, NY: Routledge, 1993, 307-320.
44. Joanna Gardner-Huggett, "Redefining Self-Representation: Julia Thecla's Full Moon (1945)," 536.
45. "Portrait Painter's First Effort Is Gaining Patron's Confidence," *The Washington Post*, Wed., Feb. 5, 1936, Microfilm, Macena Barton Papers, Reel 1991, 25 No. 4079, Sec. 705, Archives of American Art, Smithsonian Institution, Washington, DC.
46. Gardner-Huggett, "Redefining Self-Representation: Julia Thecla's Full Moon (1945)," 534.
47. Ibid., 536.
48. Ibid., 536.
49. Joan Riviere, "Womanliness as a Masquerade," Wendy K. Kolmar and Frances Bartkowski, eds., *Feminist Theory: A Reader*, 3rd. ed., (New York: McGraw, 2010), 133.
50. Collection of Mr. and Mrs. Harlan J. Berk. Chicago, Illinois.
51. Weinginer, "Macena Barton," 89
52. Ibid.
53. Ibid.
54. Ibid.

Bystander Art: Hannah Höch's Nazi Years

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Abstract This essay aims to explain how German artist Hannah Höch's political and social position affected her art practice during the Third Reich. A comparison of political photomontages from her Weimar years to her Nazi years reveals the artist's shift from a politically engaged individual to a bystander living under the conditions of inner exile. Höch's response to the National Socialists was ultimately conflicted. While this may complicate her image as an alternative, politically active Dada artist, it paints a more real and nuanced portrait. Further, this essay reclaims Höch's little-discussed Nazi years from scholarly dismissal.

During the Third Reich, the Nazis targeted the arts, purposefully manipulating culture for their revolutionary campaign. Many artists fled when faced with the Nazis' art agenda, which was characterized by a dislike of contemporary, modernist, or avant-garde work. Some, however, stayed, Hannah Höch among them, "painting quietly, and without exhibiting"¹ during the Third Reich, like many artists who went into inner exile.

However, Höch's "quiet" artistic existence *was* punctuated by the Nazi menace, which affected her art production, social life, and professional means. Her status as an inner exile deserves a closer look along with her particular political and artistic position within the Third Reich. Like many, her position is complicated. Though usually classified as a bystander, her history is marked with potentially more conflicting responses. On the one hand, Höch refused to support the National Socialist decree requiring her to profess her Aryan heritage to the *Künstler-Laden*, a Berlin artist collective. But, on the other, she considered accepting a possible commission from the *Luftfahrtministerium*, Hermann Goering's ministry of civil aviation in Berlin.² How can her position as an artist bystander be understood and what does it mean for Höch's practice of art? An analysis of her artistic shift from her well-known Weimar years to her little-discussed Nazi years reveals Höch's ambivalent position. As her art moves from the politically charged social critique of her Weimar years to the ambiguous photomontages of the 1930s and 40s, so does the artist herself. Ultimately, an examination of Höch's life and art during the Third Reich exposes how the individual intersected with the horrific history of National Socialism. An analysis of one "out-

sider's" story in Nazi Germany provides one more window into the history of the Third Reich and its actions.

In recent years, Höch has become an icon in German art history, almost the German equivalent to Georgia O'Keefe.³ Though she is famous, scholarship about her and her work is mostly limited to her Dada years in the Weimar Republic and to her broken, subversive, and confused political photomontages of that period. In fact, Höch's subsequent art has been dismissed by a number of art historians.⁴ Maud Lavin, the foremost American art historian on Höch and largely responsible for the recent American interest in her, rejects Höch's Nazi history, authoritatively circumscribing boundaries and interests of Höch's artwork and life: "There were inevitably questions about Höch's relationship to the Nazis (she fled to the exurbs of Berlin and stayed), her bisexuality (she never proselytized for bisexuality or lesbianism), her irony (why couldn't she be more like John Heartfield with his bold, propagandistic slogans?)"⁴ For Lavin, Höch's life in the Third Reich can be summed up in a single parenthetical phrase—along with her bisexuality and "irony."

Similar to the omission and rejection of Höch's Nazi years, scholarship on inner exile artists is lacking in crucial ways. Much has been done to analyze artist-exiles from Nazi Germany and their symbiotic relationships with their new host countries, but the history and understanding of artists living in inner-exile has received much less attention.⁵ An analysis of Höch's life in Nazi Germany must be anchored within this collective history of inner exiles. Inner exile within one's own country operates similarly to exile in foreign nations. For Höch, inner exile seems character-

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[†] Indeed, this essay is based primarily on the single English-language source I found in my research on Höch's Nazi years. It is certainly not an overstatement to claim that scholars have qualitatively dismissed the art Höch's produced during National Socialism—the (un)availability of literature attests to this.

ized by what she described as “great loneliness.”⁶ Indeed, life as she knew it ended with the Nazi assumption of power. Once in power, party leaders systematically invaded and restructured cultural organizations. She was no longer able to exhibit her work and her professional artistic life stagnated. Organizations like the *Künstler-Laden*, which she had once been part of, became unattractive to her as they adopted the Nazi line. Through the Reich Chamber of Culture, the Nazis actively took over and exploited cultural institutions. The Reich Chamber of Culture’s mission was “...a two pronged one, entailing both the ‘promotion of creative and productive forces’ and the ‘eradication of unworthy and dangerous elements’.”⁷ In early 1933, the *Reichskulturkammer* initiated a purge of all non-Aryans in the arts.⁸ Under these circumstances, many artists left. Höch stayed, but Germany changed, leaving her lonely and internally displaced.

Höch was alienated in her own country, her status as an outsider quickly compounding to a dangerous degree. She was very much an artist with a “Bolshevist” past—a term the Nazis used to describe various dangerous or undesirable groups in Germany, including Jews and communists—that the Nazis were intent on neutralizing and eliminating. Sabine Eckmann discusses the history of confronting exiles from and within Nazi Germany: “Along with the systematic rehabilitation of the modernist art that the Nazis had denigrated went an avoidance of the issue of exile. Thus, no one asked how individual artists had reacted to the political ideologization of their works or to National Socialism itself—or indeed why they had chosen to leave Germany or to stay there. Instead, all modernist artists were tagged as victims [by art historians].”⁹ But were they victims? Were they, perhaps, even perpetrators? What was Höch’s specific position?

Historian Raul Hilberg provides a set of models to identify the three primary positions within the Holocaust: perpetrators, victims, and bystanders with “a separate set of attitudes and reactions” for each group.¹⁰ Considering that Nazi intervention in Höch’s life remained relatively small and non-invasive—characterized at most by the Nazis’ shutting down an exhibition of forty photomontages at the Dessau Bauhaus in summer 1932—Höch seems best described as a bystander.¹¹ She was not Jewish and, apparently, not politically active enough—perhaps not well known enough—for the Nazis to bother much with her. She never saw violence directed at her. She was just a bystander, not participating in either the horrors perpetrated against the Jews or in resistance to them. Hilberg writes, “Most contemporaries of the Jewish ca-

tastrophe were neither perpetrators nor victims. Many people, however, saw or heard something of the event... They were not ‘involved,’ not willing to hurt the victims and not wishing to be hurt by the perpetrators.”¹² Höch was aware of what was happening to the Jews, noting the pogroms against the Jews on *Kristallnacht* in her diary.¹³ While Jews throughout Europe were being persecuted, Höch went on numerous road trips, hardly a critical and active response to Jewish persecution.¹⁴ Hilberg writes that “All of these people thought of themselves as victims, be it of war, or oppression, or ‘fate’.”¹⁵ History seems to agree, considering Eckmann’s contention that all modernist artists were tagged as victims. It seems clear that Höch primarily considered herself a victim.

Particularly in Germany, bystanders were closer to perpetrators in terms of moral responsibility.¹⁶ Her complacency is understandable given the Nazi takeover of most cultural organizations and their successful infiltration into art communities. In many ways, they eliminated a space for resistance.¹⁷ The role of the bystander is a lonely one, especially in hindsight. It seems that Höch was most interested in her own continued survival and maintenance of daily life. Characterized as Dada’s “good girl,” she might have earned that label in her Nazi years as well.¹⁸ Höch’s reaction to Nazi Germany was to simply disengage as a bystander.

Höch’s *Gleichschaltung*, translated as “falling into line”—here meaning with the Nazis—is evidenced in her own art practice. Leading a “quiet” life, Höch retreated from active artistic life after her friends left Germany and the Nazis seized the cultural institutions. Her fear of the Nazis forced her to become more insular and self-interested as she attempted to avoid the horrors around her. It was not a choice, but a defensive response to the reality of Nazi Germany. Her art changed in much the same way as her situation. While pointed political and social critique characterize her Weimar years art, Höch “disguises” and “veils” her photomontages during the Third Reich, making them more ambiguous and acceptable within the prevailing ideological, political, and social climate.¹⁹ In the 1930s and 40s, Höch produces more aesthetic works, photomontages that lack the critical message of the Dada years.[†]

A comparison of Höch’s political photomontages illustrates the shift in her work from specific to general, from a politically active individual to a bystander. One of Höch’s most famous pieces, *Cut with the Kitchen Knife Dada through the Last Weimar Beer-Belly Cultural Epoch of Germany* (1919–1920), serves as an

[†] A longer version of this essay included a second comparison of two photomontages representing Höch’s interest in the female subject: *Untitled* (1921) and *Made for a Party* (1936). *Made for a Party* offers a more stereotypical, simple portrait of woman while *Untitled* complicates our understanding of gender through specific logos, machine parts and products.

example of political critique. A large, densely layered photomontage, it “offers an entire social panorama of the Weimar Republic.”²⁰ Different sections of the work are devoted to different politics: Dada and anti-Dada.²¹ The photomontage uses images of “political leaders with sports stars, Dada artists, and urban images”—specific individuals and identities.²² Karl Marx and Lenin are aligned with Dada, while Wilhelm II represents the anti-Dada wing.²³ It creates a political vortex made of specific individuals and specific politics. A reading of the piece is based on an understanding of these particular persons and politics. Contemporary German viewers would have recognized the visual lexicon of her images immediately.²⁴ Cut with the Kitchen Knife speaks with specific political imagery. It epitomizes Höch’s Weimar years: specific, political, active, and densely layered.

Compare that to *The Eternal Folk Dancers* (1933), an artwork that has been read as representing the Nazis. Instead of specific individuals, political imagery and text, *The Eternal Folk Dancers* contains two men constructed from diverse component parts, dancing the Schuhplattler, which is referenced in its German title, *Die Ewigen Schubplattler*. “The ‘Schuhplattler’ is a fast-paced Bavarian folk dance in which thighs, knees, and heels are slapped. It was especially popular during the National Socialist era...”²⁵ Höch’s portrayal of the men and their dance is anything but becoming. The dancers are convoluted, one with a child’s head and the other with a mish-mash of features on a primitive sculpted head. Their legs are flung high; one wears a traditional German costume with suspenders and the other is naked with his small penis exposed. While this photomontage in some ways refers to her earlier Weimar works—it is a humorous and scathing parody of a political party—its imagery and critique are less pointed. The figures are not given a particular identity—there are no Wilhelm IIs or Hitlers—and there is no specific reference to the Nazis at all. A more subtle critique presents itself through the title and its association with the National Socialists.

The politics of 1937, a year of transition for the Nazis, frame Höch’s shift to bystander art. In 1937 anti-Semitic policy was radicalized, preparing Germany for an escalation of violence and racism. Culture was exploited as part of the political agenda, an essential component of the propaganda machine.²⁶ In the words of Alan Steinweis, “In 1936 and 1937, the minister [Goebbels] used the Reichskulturkammer in a multifront campaign against musical atonality, jazz, degeneracy in the visual arts, and political humor in the cabaret.”²⁷ It is in this environment that Höch’s position becomes complicated. She and her boyfriend, Heinz Kurt Matthies, spent most of the year traveling, taking a six-month

road trip through Southern Germany.²⁸ They visited Munich as the *Entartete Kunst* exhibit opened. This exhibition grouped and identified “degenerate” art that disgusted the Nazis and was antithetical to their policy. The pathologization of the artworks and artists as mentally ill and bolshevist in the *Entartete Kunst* show was “...the final stage in that process of institutional conformism...”²⁹ Höch visited the exhibit on September 11 and 16. She wrote in her diary, “The most important works of the post-World War I period are represented here. All museums and public collections are represented here. After the public outcry, it is astonishing how well-behaved the public is. Many faces are closed and also quite a lot of opposition can be detected. Scarcely a word is spoken.”³⁰ She revisited the exhibit twice in 1938: once in Berlin and once in Hamburg.³¹ While her work was not included in the exhibit (though one section was devoted to Dada), Höch was implicated. A contemporary literary equivalent to the “degenerate” art show, described Höch as an affiliate of the *Novembergruppe* who signed the open letter of 1921.³² Her art and her political history, intertwined in the spirit of Dada, became problematic and dangerous in Nazi Germany. The government itself aligned Höch with degeneracy, communism, and the Jews. The dangerous possibility of “cleansing” was very real. Ultimately, for Höch the exhibition amounted to “direct coercion by the state” which “had the notable effect of creating an environment of anxiety in which self-censorship by artists became the norm.”³³

Höch may not have been entirely disengaged with Nazi Germany. In juxtaposition to her safe anti-Nazi actions, Höch visited the *Luftfahrtministerium* in 1937 and brought 11 artworks with her. The artwork appears to be a commission from the ministry,³⁴ perhaps indicating another way in which Höch fell into line with the Nazi regime. A visitor to the *Entartete Kunst* show, an opponent of the *Künstler-Laden’s* demands, and a victim of Nazi cultural policy at the Dessau Bauhaus, Höch complicates our understanding of her position by her possible government commission. It appears that Nazi control and manipulation of cultural agencies and institutions may have worked on Höch in life and in art like many Germans as policy was radicalized.

Ultimately, Höch’s position as a bystander is complicated. In 1933, Höch refused to assert her race to the *Künstler-Laden*, but by 1942, she submitted a membership to the *Reichskammer der bildenden Kunst* (Reich Chamber of the Fine Arts), which included her affirmation as racially Aryan.³⁵ Her experience demonstrates that true neutrality is hard to achieve and even harder to maintain. For Höch, the realities of Nazi Germany and inner emigration forced her to become more insular and personally concerned in an effort

to survive, disengaging with her past political and social identity. Like the artist, her photomontages moved toward the Nazi line, not ideologically, but to a point where she could live and work under the radar and keeping her hand. This essay is not meant to deface Höch's alternative, subversive, and political Dada years. Instead, it paints a more nuanced and complicated portrait of the artist—a portrait that is ultimately more real. Höch's story is not unique, but it provides one specific and much-needed look at the often ignored artist-bystander in Nazi Germany.

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1. Alan E. Steinweis, *Art, Ideology, and Economics in Nazi Germany: The Reich Chambers of Music, Theater, and the Visual Arts* (Chapel Hill: University of North Carolina Press, 1993), 127.
 2. Kristin Markholm, "Chronology" in *The Photomontages of Hannah Höch*, edited by Maria Makela and Peter Boswell (Minneapolis: Walker Art Center, 1996), 196.
 3. Maud Lavin, "The Mess of History or the Unclean Hannah Höch" in *Inside the Visible: An Elliptical Traverse of 20th Century Art*, edited by M. Catherine De Zegher (Cambridge: The MIT Press, 1996), 117.
 4. *Ibid.*, 119.
 5. Sabine Eckmann, "Considering (and Reconsidering) Art and Exile" in *Exiles and Emigrés: The Flight of European Artists from Hitler*, edited by Stephanie Barron with Sabine Eckmann (New York: H. N. Abrams, 1997), 30.
 6. Hannah Höch, "Lebensüberblick" in *Cut with the Kitchen Knife: The Weimar Photomontages of Hannah Höch*, edited by Maud Lavin (New Haven: Yale University Press, 1993), 214-215.
 7. Steinweis, 103.
 8. *Ibid.*
 9. Eckman, 31.
 10. Raul Hilberg, *Perpetrators, Victims, Bystanders: The Jewish Catastrophe 1933-1945* (New York: HarperCollins Publishers, 1992), ix.
 11. Markholm, 196.
 12. Hilberg, xi.
 13. Markholm, 198.
 14. Markholm, 196-198.
 15. Hilberg, 195.
 16. *Ibid.*, 196.
 17. *Ibid.*, 197.
 18. Carolyn Lanchner, "The Later Adventure's of Dada's 'Good Girl': The Photomontages of Hannah Höch after 1933" in *The Photomontages of Hannah Höch*, edited by Maria Makela and Peter Boswell (Minneapolis: Walker Arts Center, 1996), 129.
 19. Lanchner, 131.
 20. Maud Lavin, *Cut with the Kitchen Knife: the Weimar Photomontages of Hannah Höch* (New Haven: Yale University Press, 1993), 19.
 21. *Ibid.*
 22. *Ibid.*
 23. *Ibid.*
 24. Lanchner, 130.
 25. Maria Makela, "Exhibition Plates 26-74: The Interwar Period" in *The Photomontages of Hannah Höch*, edited by Maria Makela and Peter Boswell (Minneapolis: Walker Arts Center, 1996), 122.
 26. Steinweis, 139.
 27. *Ibid.*
 28. Markholm, 197.
 29. Christoph Zuschlag, "An 'Educational Exhibition': The Precursors of Entartete Kunst and Its Individual Venues" in "Degenerate Art": *The Fate of the Avant-Garde in Nazi Germany*, edited by Stephanie Barron (New York: Abrams, 1991), 84, 87.
 30. Markholm, 198.
 31. *Ibid.*
 32. *Ibid.*, 197.
 33. Steinweis, 132.
 34. Markholm, 198.
 35. *Ibid.*

Beyond Reconquista and Convivencia: The Relevance of Hispano-Arab Identity for a Post-Islamic Spain

Nicholas R. Lang*

Abstract This essay argues that the politics surrounding Spanish identity frame the state's relationship to its Islamic past and present as interreligious cooperation or as that of a debauched Islamic country saved by Christianization. By making the discussion solely about this dichotomy, the discourse of Hispano-Arab identity both streamlines the intricate interreligious politics of Islamic and post-Islamic Spain and renders any discussion of Spain's present relationship to its Muslim citizens irrelevant. Structured by a close reading of various texts, this essay may help us understand the relevance and the place of Islam in a modern macro-state Europe.

In 1978, Edward Said's book *Orientalism*, redefined how we think about cultural interaction, positing that the relationship between the cultures of East and West was based on power and domination. Said characterized the powers of representation inherent in the colonial relationship, as the "West" assumed the right to underwrite and define the "exotic" cultures they encountered. In creating this idea of the exotic "East," Western writers, analysts, observers and historiographers created a language by which to discuss "the Other," discursive boundaries which had to be underwritten and upheld by further writing in the Orientalist field. In doing so, Orientalists created an essentialized East out of disparate cultural threads, privileging one way to think about the "East," and one version of "Eastern" reality.

Since the publication of Said's *Orientalism*, scholars have continued to discuss and debate how powers of discourse work upon and control the cultures of Asia and the Middle East, but they have largely ignored how historical Orientalism affected the "West's" definition of itself. In the Spanish and Portuguese Iberian Peninsula, the issue of the Eastern "Other" has largely been an internal matter, subject to the authority of the current ruling powers and the discursive authority of later historiographers. Throughout Spanish history, these observers have sought to streamline a confusing, multiethnic reality by essentializing Iberia's diverse and ever-changing realities.

Various scholars and historiographers achieved this by erecting staid boundaries of identity: us or them; Muslim, Christian or Jewish; or by classifying Iberian history as singularly defined by either a Christian reconquering of a religiously debauched Spain or by painting Spain as a fallen interfaith Eden. I argue that

these exclusive boundaries cannot begin to describe Spain's past or present Hispano-Arab identities, because these conversations reduce Islamic legacy merely to discussions of Islamic days gone by. In so doing, we render the intricate politics of medieval Iberia totally irrelevant for its modern counterpart.

Using the lens of Said's *Orientalism*, I will trace the various discursive frameworks that define Spanish identity discourses, detailing how observers and scholars uphold historical boundaries of Hispano-Arab Spanish identity. I begin with a discussion of the Romanticist vision of Spanish identity, indicating the ways in which convivencia ideologies of medieval interreligious harmony posit an image of Iberian interfaith cooperation insufficient to describe its relevance to everyday life. I then show how developments in Spanish history led also to the Medievalist school of Reconquista discourse, which sought to create a homogenous Christian state. Having defined both discourses of the Iberian self, I illustrate how these boundaries of thinking detach Spanish citizens from a real connection between the realities of the past and present, at a time when its realization is increasingly relevant. Lastly, I will illustrate the ongoing cultural amnesia that arose as a byproduct of these limiting discourses of Spanish identity and discuss its effect on modern Spanish life.

The Romantic Conversation: The Making of a Spanish Convivencia

Towards the end of the 2007 PBS documentary, "Cities of Light: the Rise and Fall of Islamic Spain," the filmmakers caution modern observers and analysts not to read the realities of the present into the history of Spain. However, to look for explanations of our contemporary conflicts in the scattered data of the past is a common pattern of mythmaking and historiography. Although they did not point fingers, one can assume that the filmmakers

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were addressing the Medievalist and Arabist-Romanticist camps of Spanish history. The former stressed Spanish nationalism and the role of Reconquista in shaping the history of Spain, and the latter focused on the religiously and ethnically delineated pluralism and inter-religious convivencia of medieval Iberia.

Reconstruction of the past can take many forms. I will deal first with yet another thread of Spanish mythmaking, our tendency to romanticize Iberia. Lucy Crockett's glossy 1957 travelography, *Kings Without Castles*, largely functions as a high-minded guidebook. But her writing also enters into a Saidian—style discourse with other authors analyzing Spanish culture and identity. The travelographies of Washington Irving and Richard Ford further built a Hispano-Arabic Romanticist discourse, a framework which would provide a blueprint for American Orientalist thinking about Spain and help set the discursive boundaries for Crockett's work.

Written during the Franco-era, Crockett's travelogue details her experiences with the Spanish people and how they match America's image of Spain in the 1950's. In the Spanish themselves, Crockett initially finds the stereotypical image of an emotional people shaped by survival in the country's harsh conditions. Her strong, vibrant Spaniards are guided by "emotion rather than reason" and think only in "terms of symbols rather than facts".¹ However, as her journey continues, her writing moves away from these early Orientalist tropes and increasingly argues for the multicultural, romantic visions of Spain that dominate the Arabist school of Hispano-Arab historiography.

No cultural motif is more important for Arabist scholars than the "culture of translation" which arose in medieval Iberia, as the culture of Toledo provided a haven for scholars and translators, such as Michael Scot of England. Although many later historians characterized the fraught history of medieval Iberia as a clash of civilizations, the cases of Scot and St. Thomas Aquinas stress the transmission allowed in the contact between civilizations. Arabists stress that this Iberian culture of translation united the East and West, rather than merely being a one-way transmission of information. In structuring their visions of the realities of Hispano-Arabic identity, they are not wrong to highlight cultures of translation, learning, and convivencia when recreating Muslim Iberia for a modern audience, as these "laboratories of interfaith dialogue" were "less exotic than the stereotype."²

A Reconquista: The Europeanization and Christianization of Spain

In the Arabist accounts of this period of Spanish history, this burgeoning Christian nation-state moved away from an Arabic multi-culture, which could accommodate many lifestyles, to homogenization that compelled all citizens to adhere to the same language, culture, and religion. Throughout the next few centuries of religious purge through auto-da-fe, the identity of the Inquisition and post-Inquisition Christian Spanish state are in a constant state of negotiation and renegotiation, as the state worked to solidify its nation-state status. This was finally achieved in the 18th century. To support this process, Spanish rulers and revisionist historians attempted to negotiate internal and external Hispano-Arabic strife by constructing a discursive reality befitting the glory of the Christian Spanish empire.

After the defeat of the Spanish navy by the United States in 1898 and the perceived international embarrassment that followed, the conversation regarding the Spanish empire turned to a single question: "What Went Wrong?" In answering this question, Spanish Christian nationalists also took comfort in the christianizing ideology of the Reconquista movement, particularly the powerful image of the warrior El Cid cleansing Spain of its Islamic pollutants. This partnership speaks to the many ways scholars and bureaucrats worked together to christianize Spain.

However, further examination broadens the scope of this historical, multifaceted conflict, as any Reconquista policy served both to christianize the Iberian Peninsula and Europeanize the continent.³ To wit, religio-political alliance with the Papal Crusade of subjugating Islam throughout the continent offered Spanish Christians the armies, funding, and political will necessary for sustained conflict. The centralization of authority over Muslim-Christian warfare underlies a shift in the geography and profundity of the conflict, as the christianization project increasingly became both civilizationally and continentally defined.

A Divided Spain: The Drawing of Religio-Cultural Discourses for a Fortress Europe

Although this Christian camaraderie predated the formation of the European Union (EU), this interstate phenomenon was one of the first steps toward the geo-political segregation of Spain and Morocco, of Europe and Africa. Scholar David Joseph Wellman takes the notion of a culturally-divided Spain further, as the increasingly christianized modern Spain is forced to choose between the exclusive realization of its African and European cul-

1. Crockett, Lucy Herndon. 1957. *Kings Without Castles*, 70-71.

2. Fletcher, Richard. 1992. *Moorish Spain*, 2.

3. Lomax, Derek W. 1978. *The Reconquest of Spain*.

tural debts. Although many used to joke that Europe ended at the Pyrenees mountains, the inclusion of Spain in the EU offered Spain technological progress and full membership in a European society. More importantly, in the last decade, the Spanish people themselves have embraced a European identity, although this shift faces a degree of contestation.

This contemporary embracing of European identity comes at the expense of Spain's Muslim heritage, as the EU continues to pressure Spain to further curtail the illegal immigration of Moroccans across the Strait of Gibraltar. Contemporary conflicts between Spain and Morocco represent a history of strained relations between Spain and Morocco, mostly over land and resource issues. These disputes mirror the growing overall tension and rivalry between the two countries, with Morocco unable to advance itself economically by joining the EU. Although recent findings show that anti-Islamic Spanish nationalism may not be as pervasive as it once was, contemporary Spain faces many of the same multicultural issues as medieval Iberia and the fledgling Spanish empire. The current debate in the era of the European Union largely centers on issues of Spanish policy and identity. As the European Union and various far right groups pressure Spain to halt North African immigration, scholars have attempted to assess its effect on both Europe and Spain. An examination of the popular consciousness toward the development of Spanish immigration policies and Spain's treatment of Moroccan citizens reveals patterns of exceeding nationalism and exclusivity, especially regarding displaced Maghrebis.⁴

Until Franco came to power, Spain's borders and policies were designed to keep people in; however, the advent of SIVE technology—the border surveillance system monitoring illegal entrance to Spain through the Strait of Gibraltar—now endeavors to keep people out. Further upholding this nationalist project, modern Spain also endeavors to discourage the immigration of unwanted others through the enactment of prejudicial legislation that encourages the replacement of Moroccan manual laborers with lighter-skinned workers from Poland and Romania. Scholars Inigo Moré and Naomi Klein both detail how Morocco perennially suffers from its relationship with Spain; their fraught geopolitics only emphasize their historically loaded intercultural differences.⁵

Andalusia Syndrome: The Effects of Spanish Identity Discourses on Popular Consciousness

As scholars weigh the recent popular and official shifts concerning Spanish immigration, we can see that the discourse surrounding Spanish convivencia is as contested as ever. This development of modern Spanish consciousness finds that Spain's Muslim problem is not only an external policy issue but also an internal conflict of coming to terms with the Spanish nation's past, often termed the "Andalusia Syndrome". In doing so, Spain has routinely distanced itself from its Muslim heritage, its neighbors and citizens, just as the Iberian Moors distanced themselves from the Middle East to assert their own cultural identity.

Although Arabist and Romanticist scholars mourn what Spain lost through these geopolitics, including its status as a "meeting ground" for Europe and Africa, virtually nothing has been said about the continuing influence of the Muslim past on Spain.⁶ A byproduct of the tensions of the past and the present, the perennial forgetting of Spain's Muslim legacy, called the "Andalusia Syndrome," continues to afflict Spanish Muslims, the target of much vitriol and violence. But another sort of Andalusia Syndrome also reveals itself in scholars like Iftikhar H. Malik, who purport to deal with Muslims in Spain but sidestep any discussion of contemporary identity issues.

Although the christianizing religious projects of the Pope and the Visigoths were not entirely successful, the Reconquista, Inquisition, and expulsion could not totally remove Islam and its ongoing effects on Spain. To understand the contemporary conflicts between Christians and Muslims, we must no longer limit our discussion of the influences of Muslim Spain to the past. By accepting the Romanticist version of an Islam lost to Spain, we obscure its influences on Spanish identity, modern Spanish consciousness, and its significance for contemporary politics, making any discussion of these subjects increasingly irrelevant.

4. Martin, Michael. 1999. "Fortress Europe' and Third World immigration in the post-Cold War global context."

5. Inigo Moré. 2004. "The Economic Step Between Neighbours: The Case of Spain-Morocco;" Naomi Klein. 2003 "The Rise of the Fortress Continent."

6. Malik, Iftikhar H. 2004. *Islam and Modernity*, 31.

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Online Aggression/Victimization and Adjustment Among Emerging Adults

Jessica E. Twardowski, Clare L. Kennedy and Michelle F. Wright*

Abstract The purpose of the study was to investigate how online aggression and victimization relate to the adjustment difficulties (i.e., depression and anxiety) of emerging adults (N=470). We examined two forms of online aggression and victimization (relational and verbal). Both forms of aggression and victimization were positively correlated with adjustment difficulties. The regression results show that victims of verbal aggression displayed depressive symptoms, while victimization of relational aggression was not a significant predictor for either depression or social anxiety. In contrast, aggressors who engaged in relational aggression exhibited depressive and social anxiety symptoms, while verbal aggression was not a significant predictor for either depression or social anxiety.

Introduction

Society has come to depend upon the Internet to such an extent that many could not imagine a life without it. The convenience and rapid transmission of many different types of information make the Internet essential technology. College students and emerging adults are the age group with the highest Internet usage (Gordon, Juang & Syed, 2007). This frequency may be due to the Internet's importance in functioning within an academic environment, as well as for the wealth of information and social networking opportunities it provides. High Internet usage may have significant influences on adjustment in emerging adulthood, a transitional period of development between adolescence and adulthood, in which many changes in social, emotional, and physical contexts impact the individual (Riggs & Han, 2009).

College students are found to be at great risk for problematic Internet usage including online aggression (Caplan, 2007). The negative consequences of adjustment to online aggression are similar to that of real-life aggression. Studies examining adjustment to real-life aggression prompted the present study by extending the examination of adjustment consequences to online aggression (Caplan, 2007; Raskauskas & Stoltz 2007; Ybarra & Mitchell, 2004)). Adolescent victims of both forms of bullying (traditional school bullying and cyberbullying) report feelings of sadness, helplessness, and, in extreme cases, suicide (Raskauskas & Stoltz, 2007). Both adolescent victims and aggressors of cyberbullying were found to be at a greater risk for negative con-

sequences such as substance abuse and psychosocial problems (Ybarra & Mitchell, 2004).

Although previous research offers insight about the negative consequences of online aggression and victimization, there are still limitations in the literature. First, the majority of the studies lump online aggression into one category, failing to distinguish between subtypes of aggression. This limits our understanding of the impact of different forms of online aggression (relational and verbal) on adjustment. Second, previous literature primarily examines the adjustment of online victims; however, little is known of the adjustment issues of online aggressors. Studies show that school bullying in adolescents is a predictor for adjustment issues (Ybarra & Mitchell; 2004, Raskauskas & Stoltz, 2007). Similar findings may be true for online aggressors in an older age group. Third, although previous research has studied emerging adults' (18 - 25 year olds) online aggression, few studies have examined the links between adjustment and online experiences. A thorough examination of potential forms of online aggression/victimization is critical for understanding adjustment issues among emerging adults.

The Current Study

The current study examines each of these limitations and categorizes online aggression into two forms: verbal (e.g., insults) and relational (e.g., rumor spreading). The literature shows that victims of online aggression respond by withdrawing and by feeling lonely and ostracized (Ybarra & Mitchell, 2004). Thus, we hypothesized that victims of online verbal and relational aggression would experience both symptoms of depression and social anxiety. For aggressors, the literature suggests that social anxiety

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plays a large role in engaging in aggression (Pierce, 2009). This may be due to the aggressor's need for social dominance in an environment that he or she can control (Ybarra & Mitchell, 2004). Thus, online aggressors are hypothesized to report symptoms of depression and social anxiety for both forms of online aggression. Because of the limited research on the adjustment of online aggressors, this hypothesis is exploratory.

Method

Participants

Participants (N= 470, 330 female) for this study were recruited from a Midwestern university psychology subject pool and fell into the 18 - 25 year old age range of emerging adulthood (M=19.56, SD=1.52). The ethnic breakdown of the sample showed that Caucasians (63.9%) were the most prevalent, followed by Hispanic/Latino (18.2%), Asian (7.9%), African American (6.6%), Other (3.0%), and Native Hawaiian (0.4%) participants.

Measures and Procedure

After giving informed consent, participants completed a demographic questionnaire followed by CEQ aggressor questionnaire, CEQ victim questionnaire, and then the IDAS.

Cyber Experience Questionnaire

The Cyber Experience Questionnaire (CEQ) is a self-report measure assessing how often (0 = "never," 8 = "daily") participants inflict through, and are victimized by, online relational aggression (e.g., spread rumors/have rumors spread about oneself), and verbal aggression (e.g., tease someone/been teased by someone). The Cronbach's alphas were adequate for relational victimization (two items, $\alpha = .80$), verbal victimization (four items, $\alpha = .84$), and verbal aggression (four items, $\alpha = .71$), but was somewhat lower for relational aggression (two items, $\alpha = .56$). Considering that only two items were available for relational aggression, this is an acceptable reliability.

The two forms of online aggression and victimization are continuous variables in that each participant received a score for each. In terms of the prevalence of online aggression and victimization among college students, we found that among the participants, 265 (56%) engaged in relational aggression more frequently than the average (M= 2.92, meaning once every 1-2 months). Similarly, 224 participants (48%) engaged in verbal aggression more frequently than the average (M=2.14, meaning once every 2 - 4 months). Surprisingly, victimization occurred less frequently among our participants such that only 141 (30%) reported being victimized by relational aggression (M=1.77, meaning once every 2-4 months) and 124 (26%) reported being victimized by verbal

aggression (M= 1.82, meaning once every 2 - 4 months) more frequently than average.

Inventory of Depression and Anxiety Symptoms

The study also used the Inventory of Depression and Anxiety Symptoms (IDAS) to examine the adjustment of college students (Watson, et al., 2007). We used the general depression (e.g., "I felt depressed") and social anxiety (e.g., "I was worried about embarrassing myself socially") statements of the IDAS to examine how participants felt during the past two weeks (1 = "not at all," 5 = "extremely"). There were 20 items that assessed general depression and five items that assessed social anxiety. The Cronbach's alphas were adequate for general depression ($\alpha = .89$) and social anxiety ($\alpha = .82$).

Results

Correlations

Eight sets of bivariate correlations were completed between adjustment difficulties (depression, anxiety), and the two types of online aggression and victimization (relational and verbal). All correlations were significant (see Table 1).

Table 1

Correlations between adjustment and online aggression and victimization.

	Depression	Anxiety
Online Victimization		
Relational Aggression	.14*	.14**
Verbal Aggression	.24***	.20***
Online Aggression		
Relational Aggression	.17**	.20***
Verbal Aggression	.30***	.11*

Note: *p<.05, **p<.01; ***p<.001

Multiple Regressions

We conducted four sets of multiple regressions in order to examine the unique associations of each form of aggression/victimization with adjustment outcomes. We examined two different models: one for victims and one for aggressors while controlling for gender. Each model was significant as reflected by the R² values (see Table 2). Depressive symptoms were exhibited in aggressors who engaged in relational aggression, and in victims who were victimized by verbal aggression. Social anxiety symptoms were found to be significant in aggressors who engaged in

Table 2

Multiple Regressions of adjustment using online aggression and victimization.

	Depressive Symptoms				Social Anxiety Symptoms			
	B	S	β	R ²	B	S	β	R ²
Model 1—Aggressors								
Gender	.60	1.16	.03	.17*	-.45	.49	-.05	.21***
Relational	.28	.14	.14*		.19	.06	.19***	
Verbal	.09	.12	.05		.03	.05	.03	
Model 2—Victims								
Gender	2.38	1.19	.13	.26***	-.06	.51	-.01	.18***
Relational	-.16	.21	-.07		.06	.08	.06	
Verbal	.34	.11	.30**		.07	.05	.14	

Note: *p<.05, **p<.01; ***p<.001

relational aggression, while victims exhibited no significant social anxiety symptoms for either verbal or relational aggression.

Discussion

The primary aim of our study was to identify whether victims and aggressors of online aggression experienced adjustment difficulties. We successfully identified the links that both forms of aggression/victimization (e.g., relational and verbal) had with adjustment difficulties. After finding significant correlations, we conducted multiple regressions to investigate how both forms of aggression/victimization uniquely predicted adjustment difficulties.

Consistent with our hypothesis, aggressors and victims did experience adjustment difficulties in relation to online aggression and victimization. Specifically, for victims we hypothesized that both relational and verbal aggression would produce symptoms of depression and social anxiety. While the overall models were significant in regards to victimization, only verbal aggression uniquely predicted depressive symptoms. Relational aggression was not a predictor for either depression or social anxiety symptoms. Interestingly, neither relational nor verbal victimization uniquely predicted social anxiety symptoms. This finding implies that emerging adults who are victims of online verbal aggression may adjust negatively by experiencing depressive symptoms.

In relation to aggressors, we hypothesized that engaging in both forms of aggression would predict both depression and social anxiety. Our regressions showed that although the overall models for aggressors were significant, only relational aggression predicted adjustment difficulties for depression and social

anxiety symptoms. In contrast, online verbal aggression failed to show a unique association with adjustment difficulties. This finding highlights the necessity of distinguishing between various forms of aggression. The results from both the online victimization and aggression models suggest real life implications for the adjustment of emerging adults, as the Internet provides yet another environment for social interaction to take place.

Strengths and Limitations

Our study provides an important step towards bridging gaps in the literature regarding online aggression and emerging adults. We examined both aggression and victimization using two specific subtypes of online aggression that had previously been overlooked. Emerging adulthood is a new transitional period of development which has recently been identified and is clearly lacking in the literature. Hopefully our data will provide useful information for further studies on prevention pertaining to online aggression and victimization. We found that a large percentage of participants are engaging in or experiencing these behaviors and are also having significant adjustment issues. This result implies that online aggression/victimization is a prevalent issue among contemporary young adults and calls for more research.

We obtained our participants from a psychology subject pool in which each student of introductory psychology classes was asked to participate in research for course credit. Our study aimed to assess emerging adults' adjustment specifically in the college environment; thus our sample served our needs. However, our respondents were not representative of a diverse sample because most of the participants identified themselves as white

and female. Another major limitation of our study is that we assessed adjustment concurrently. Thus, we cannot draw the causal inference that the adjustment difficulties our participants encountered were due to their various online experiences. In other words, based on our data we cannot conclude whether the online behaviors caused the adjustment difficulties or whether the adjustment difficulties caused the online behaviors. Longitudinal research is needed to confirm whether online aggression impacts adjustment directly.

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The Influence of Reader Goals and Textual Constraint on Predictive Inference Generation in the Cerebral Hemispheres

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Abstract This study used a divided visual field paradigm to investigate how reader goals and textual constraint influence predictive inference generation in the hemispheres. Specifically, participants read strongly and weakly constrained texts under instructions for study (i.e., the goal condition) or no instructions (i.e., the no goal condition). Participants then made word/nonword decisions to related target words presented to the right or left hemisphere. In the right hemisphere, strongly and weakly constrained text showed different levels of facilitation only in the goal condition. Results indicate that reader goals do influence how the cerebral hemispheres process text.

Introduction

During reading, individuals often generate expectations for what will occur next in a text (i.e., generate predictive inferences) based upon what happened previously in the text and information from their own background knowledge. For example, when individuals read the sentence, “The delicate porcelain vase was thrown against the wall”, they may predict that the vase broke next (Potts, Keenan & Golding, 1988). Although research findings suggest that predictive inferences are an important part of text comprehension (Trabasso & Magliano, 1996), it is currently unclear exactly when readers generate predictive inferences during reading. Interestingly, cognitive neuroscience research shows that predictive inferences are processed differently in the left and right hemispheres (Virtue, van den Broek, & Linderholm, 2006). Additionally, specific factors, such as the goal of the reader, have been shown to influence predictive inference generation (Linderholm & van den Broek, 2002). Based on previous findings examining hemispheric differences in reading (Virtue et al., 2006), it is possible that the goal of the reader may influence predictive inference processing in the hemispheres. Thus, the current study examined how the goal of the reader influences predictive inference generation in the right and left hemisphere.

Research suggests that predictive inferences are processed differently in the cerebral hemispheres. Specifically, it has been demonstrated that predictive inferences may be processed in both hemispheres, but how strongly the text leads to a specific outcome (i.e., the level of textual constraint) primarily influences how predictive inferences are processed in the hemispheres (Virtue et al., 2006). For example, the sentence fragment “The

cop caught the...” is strongly constrained toward the final word “thief”, whereas the sentence fragment “The car was opened by the...” is weakly constrained towards the final word “thief” (Faust & Kravetz, 1998). When a text is weakly constrained, a right hemisphere advantage is evident compared to the left hemisphere for predictive inferences (Virtue et al., 2006). In contrast, if a text is strongly constrained toward a predictive inference, inferences are processed in a similar manner in both hemispheres (see Table 1 for an example of a strongly and weakly constrained text). Thus, specific factors, such as the level of textual constraint, differently influence predictive inference generation in the right and left hemispheres.

Table 1

Sample Strongly Constrained, Weakly Constrained, Neutral Text and Target Word

Tom and Krista were standing together, holding hands. Both of them were a little nervous, but mostly excited about today. Tom imagined the future as he looked at Krista.
Strongly Constrained Text
They were just pronounced man and wife.
Weakly Constrained Text
They were just announced as college graduates.
Target Word
kiss
Neutral Text
The three women had been friends since childhood. No matter where they were, they stayed in touch. Currently, they were together to celebrate New Year's Eve. They spent the evening talking about old memories and discussing the future.
Target Word
kiss

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Another factor that may influence predictive inference generation in the hemispheres is the specific goal of the reader. For example, when individuals are instructed to read a text in preparation for an exam, they generate more predictive inferences than when individuals are instructed to read for pleasure (van den Broek, Lorch, Gufstason, & Linderholm, 2001; Linderholm & van den Broek, 2002). However, it is currently unclear how reading goals influence predictive inference processing in the hemispheres. Specifically, when readers are asked to read as if preparing for an upcoming exam (i.e., the goal condition), we predict that they will show different patterns of predictive inference generation in the right and left hemisphere than when they are not given any goal prior to reading a text (i.e., the no goal condition).

Methods

Participants

Ninety-one participants (12 male, 79 female) were assigned to the goal condition in this experiment. Specifically, these participants were told that they would be tested on the reading material throughout the study. In addition, 86 participants (21 male, 65 female) were assigned to the no goal condition. Specifically, these participants were not given instructions before reading the texts in this experiment. All participants were recruited through DePaul University's Introductory Psychology Subject Pool. Participants were right-handed as assessed by the Edinburg Handedness Inventory (Oldfield, 1971). Only right-handed individuals were recruited in the current study because they recruit primarily the left hemisphere during language processing (in contrast to left-handed individuals who often recruit both hemispheres). Due to the hemispheric variability evident in left-handed individuals, it is necessary to only use right-handed individuals to make conclusions about language processing in the brain. Participants were all native English speakers, and had no history of any neurological disorder.

Materials

The current study used three sets of 48 texts taken directly from a previous study (Virtue et al., 2006). For each text, there was a strongly constrained version, a weakly constrained version, and a neutral version (see Table 1). In addition, each set of texts had a corresponding target word that was either related to the predictive inference (i.e., in either the strongly or weakly constrained condition) or unrelated to the predictive inference (i.e., the neutral condition).

Procedure

Participants were seated 50 cm from the computer screen. To maintain this distance, all participants placed their head in a chin rest. Participants were presented with four sentence texts, which were read one sentence at a time in a self-paced manner. After reading the fourth sentence, a small fixation "+" appeared in the center of the screen for 750 millisecond (ms). After the "+" disappeared, a string of letters (i.e., a target) was presented to the left or right side of the screen for 176 ms. This amount of time was used to ensure that participants could not move their eyes to the center of the target (Bourne, 2006). To examine hemisphere processing, we used a divided visual field paradigm. In this paradigm, targets are quickly presented to either the right visual field (which are initially processed in the left hemisphere) or the left visual field (which are initially processed in the right hemisphere). Participants then decided if the target was a word or nonword (i.e., a lexical decision task) by pressing one of two buttons. Nonword targets were used to ensure an equal number of yes/no responses in the lexical decision task. After a subset of texts, participants were also asked a yes/no comprehension question to ensure that they sufficiently understood the texts. All participants also completed a practice trial before beginning the experiment.

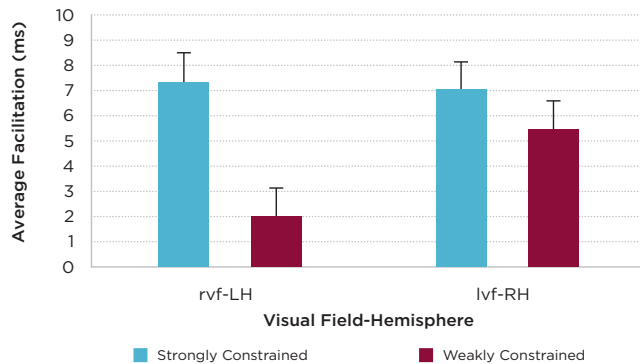
Results

Lexical decision response times to target words were collected for participants in the goal and no goal condition. To minimize outliers, the longest and shortest 1% of the data was removed within each condition (see Ratcliff, 1993 for a description of this procedure). An alpha level of .05 was used to determine significance.

To directly compare inference-related targets across the hemispheres, response times to strongly and weakly constrained targets were subtracted from response times to neutral targets (i.e., facilitation effects). Two separate repeated measures analyses of variance (ANOVAs) were conducted on the facilitation effects. One ANOVA was conducted for participants in the goal condition and one ANOVA was conducted for participants in the no goal condition. For each separate ANOVA, the independent variables were textual constraint (i.e., strong or weak) and hemisphere of presentation (right visual field-left hemisphere or left visual field-right hemisphere). The dependent variable was hemispheric processing (i.e., the facilitation effect in the left or right hemisphere). In the no goal condition, there was an interaction between visual field and constraint, $F(1, 85) = 9.38, p < .05$ (see Figure 1).

Figure 1

Average facilitation in ms for strongly and weakly constrained predictive inferences in the right visual field-left hemisphere (rvf-LH) and the left visual field-right hemisphere (lvf-RH) for the no goal condition.



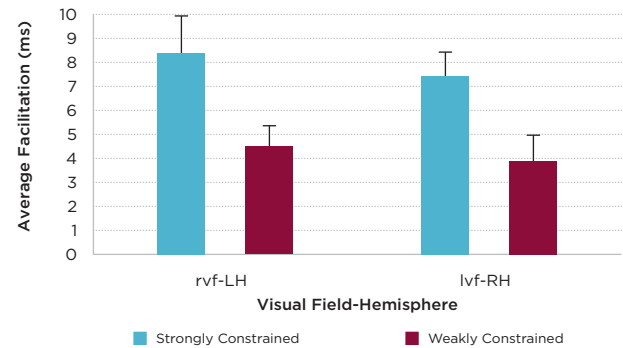
Follow up t-tests indicate that in the left hemisphere, facilitation was greater for strongly constrained targets than for weakly constrained targets, $t(85)=6.77, p < .05$, however, facilitation did not differ between weakly and strongly constrained targets in the right hemisphere. In addition, weakly constrained targets showed greater facilitation in the right hemisphere than in the left hemisphere, $t(85)= 2.02, p < .05$. In the goal condition, there was a main effect of constraint, $F(1, 90) = 19.13, p < .05$ (see Figure 2). Follow-up t tests indicate that in the left hemisphere, facilitation was greater for strongly constrained targets than for weakly constrained targets, $t(90)= 4.55, p < .05$. In the right hemisphere, facilitation was greater for strongly constrained targets than for weakly constrained targets, $t(90)= 2.43, p < .05$.

Discussion

The current findings are consistent with our prediction that reading goals influence predictive inference generation in the hemispheres. Specifically, when participants were not given a goal prior to reading (i.e., the no goal condition), they showed a right hemisphere advantage when processing weakly constrained predictive inferences. In addition, participants in the no goal condition showed no difference between strongly and weakly constrained predictive inferences in the right hemisphere. In contrast, strongly constrained predictive inferences showed greater facilitation than weakly constrained predictive inferences in the left hemisphere. The current results replicate previous findings examining the role of textual constraint in the hemispheres (Virtue et al., 2006). Interestingly, when readers were given a goal prior to reading (i.e., the goal condition), a different

Figure 2

Average facilitation in ms for strongly and weakly constrained predictive inferences in the right visual field-left hemisphere (rvf-LH) and the left visual field-right hemisphere (lvf-RH) for the goal condition.



pattern of hemispheric facilitation for predictive inferences was found. Specifically, strongly constrained predictive inferences were processed faster than weakly constrained predictive inferences in both the right and the left hemisphere. Thus, the goal of a reader does seem to influence the pattern of predictive inference generation in the hemispheres during reading.

One reason reading goals may influence predictive inference processing in the hemispheres is that when participants adopt a specific reading goal during text comprehension, they may elaborate more on information in the text. Theoretical frameworks suggest that predictive inferences are an elaborative process (e.g., McKoon & Ratcliff, 1992) and that predictive inferences only occur under some circumstances (e.g., Graesser, Singer, & Trabasso, 1994). Thus, it is possible that when readers are given a specific reading goal, such as reading to study, they pay more attention to the text and are more likely to elaborate on the text (van den Broek et al., 2001), which then changes how the hemispheres activate information related to these predictive inferences. Although we examined the hemispheric processing of predictive inferences during reading goals, future research could examine how individual differences, such as working memory capacity, influence how reading goals affect predictive inference generation in the hemispheres. Previous research suggests that individual differences, such as reading skill (Prat, Long, & Baynes, 2009) and working memory capacity (Linderholm & van den Broek, 2002), may influence how readers process text in the hemispheres. In sum, our findings suggest that reading goals are an important factor in how the hemispheres process predictive inferences under weakly and strongly constrained text conditions.

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Violating Traditional Gender Roles: The Effects of Perceived Symbolic Threat on Rationalizing Intimate Partner Violence

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Abstract This study examines factors that allow the acceptance of intimate partner violence. A total of 141 DePaul University undergraduates read one of four vignettes about a physical altercation between a dating couple that varied in terms of the type of relationship (traditional or egalitarian) and the perceived intentionality of a threat to a male partner's masculinity (intentional or unintentional). Participants rated perceptions of the altercation, including their justification of interpersonal violence, blame toward the victim, and their general feelings of anger and sympathy towards both partners. Perceived intentionality had a stronger effect on acceptance of dating violence than a couple's relationship type. When the threat was intentional, participants were more likely to justify the hitting, place blame on the victim, and have less positive feelings towards the female victim than when the threat was unintentional. Intentionality was also perceived more negatively in egalitarian relationships than in traditional relationships.

Introduction

In the United States, 1.3 million women are physically assaulted by an intimate partner each year (Tjaden & Thoennes, 2000). Numerous studies have found an increase in acceptance and perpetration of intimate partner violence due to the role of traditional gender values and/or benevolent sexism (Coleman & Stith, 1997; Johnson et al., 2005; Lichter & McCloskey, 2004; Wood, 2004; Yamawaki et al., 2007). Truman, Tokar, & Rischer (1996) found that many males who held more traditional values tended to endorse rape-supportive attitudes as well as tolerate interpersonal violence. This study also demonstrated a connection between traditional masculine identity and the acceptance of interrelational violence. Perceived threat to one's masculinity and high masculine gender role stress is also related to negative affect towards women (Franchina et al., 2001).

The attributions people make about the causes of a transgression are another powerful predictor of anger and hostility. When people find the person who offends them to be responsible for their actions, they tend to get angry and aggressively retaliate more than they would if they did not feel the offender was responsible (Weiner, 1995). Betancourt and Blair (1992) found that perceived responsibility for a negative act was positively related to anger and aggressive retaliation and was negatively related to feelings of pity and sympathy towards the person who committed the wrongdoing.

This study examines the factors that allow the acceptance of intimate partner violence; specifically, the interaction between

traditional gender values and perceived threat to a traditional gender role. I hypothesize that in a traditional context, any kind of symbolic threat (intentional or unintentional) will contribute to higher acceptance of interpersonal violence. In an egalitarian, nontraditional, relationship, only the intentional symbolic threat should yield more rationalizations for interpersonal violence than unintentional threat. In an egalitarian relationship a person will care more about the cause of the transgression than just the outcome of the threat.

Methods

Participants and Procedures

37 male and 104 female undergraduates from DePaul University's Introduction to Psychology courses participated in the study as part of a course requirement and were compensated with partial course credit for completing the confidential, online questionnaire.

The average age of participants was 19.5 years. 71 participants identified themselves as single/never married, 61 were in a dating relationship, and 3 were married. Also, 78 of the participants identified that either they or someone close to them, experienced physical aggression in an intimate relationship at least once.

Materials

Vignettes were designed to manipulate variables that might be related to interpersonal violence. The target variables in this research were type of relationship (traditional vs. egalitarian) and the perceived intentionality of the female partner's threat to the male partner's masculinity (intentional vs. unintentional). There

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were a total of four vignettes, describing (1) a traditional dating couple with an intentional threat, (2) an egalitarian couple with an intentional threat, (3) a traditional dating couple with an unintentional threat, and (4) an egalitarian couple with an unintentional threat. Couples were described as being in either a traditional (the male partner is dominant) or in a more egalitarian (both partners are equal) relationship. The altercation occurred at a bar with the male partner's friends; the woman either intentionally or unintentionally threatened her partner's masculinity. Each scenario concluded with the male partner hitting the woman as in the example below:

Jack and Lisa are in a [traditional/egalitarian] dating relationship. [Lisa likes to cook for Jack and believes it is important for a woman to care for her man and tend the home. Jack makes most of the dating decisions, always pays, and believes that it is important for the man to be able to provide in a relationship. Jack and Lisa both feel that it is important to have equal say in the relationship; they both make dating decisions equally, make dinners for each other, and take turns picking up the tab.] One day, Jack and Lisa go out to a bar with some of Jack's friends. At the end of the night, when the check comes to the table both Jack and Lisa look at the bill. When Jack reaches for the bill, Lisa stops him [in front of his friends, saying out loud, / talking under her breath so his friends can't hear her] "We both know you can't afford that." Lisa then [pays the bill in front of his friends. Lisa then hands Jack her credit card under the table so his friends would not see.] After leaving the bar, when Jack goes to drop Lisa off at her house, they get in a fight over the incident. Jack screams "how dare you humiliate me in front of my friends" and slaps Lisa across the face.

After reading each scenario, participants rated statements in response to the altercation. Each statement was developed to specifically assess responses to the scenario. Items were rated on a seven point scale (1=Disagree Strongly, 7=Agree Strongly) and assessed participants' perception of the situation, attributions of the event, and feelings towards each partner in the vignette. Examples of statements used to determine acceptance of interpersonal violence are: "Jack was justified in hitting Lisa," "Lisa deserved to be hit," and "It is at least somewhat justifiable that Jack hit Lisa."

Results

Manipulation Checks. To test whether the experimental manipulations had the desired effects, I conducted a one-way Analysis of Variance (ANOVA) on three questions related to the variables manipulated in the vignettes. To test perceptions of relationship type, participants rated the type of relationship Lisa and Jack

were in (1= Traditional, 7= Egalitarian). There was a significant effect of the type of dating relationship conveyed by the vignette and how traditional or egalitarian the couple was perceived, $F(1, 140) = 22.7, p = .001$. Participants who had read the vignette describing a traditional couple were more likely to rate the relationship as being traditional ($M = 3.07, SE = .19$) than participants who read the egalitarian vignette ($M = 4.47, SE = .21$). To test for the manipulated type of threat, participants rated how much they agreed with two statements: "Lisa intentionally humiliated Jack," and "Lisa made an effort to protect Jack's feelings." There was a significant difference between intentionality in the vignettes and participants' perception of Lisa's intentionality [$F(1, 140) = 34.61, p = .001$] and her effort to protect Jack's feelings [$F(1, 140) = 266.2, p = .001$]. For example, participants who read the vignette describing an unintentional threat tended to agree more with the statement that Lisa made an effort to protect Jack's feelings ($M = 6.12, SE = .163$) than participants who had read that the threat was intentional ($M = 2.45, SE = .154$). Thus, it appears that the experimental manipulations were effective.

Test of Hypothesis. I hypothesized that both type of threat and type of relationship described in each vignette would have an effect on the acceptance of violence. To test this hypothesis I examined the effects of the type of threat and couple relationship on the measure of extreme and partial blame using a 2 x 2 ANOVA. Extreme blame was measured through agreement to the statement "Lisa deserved to be hit." The analysis of extreme blame revealed a main effect for type of threat, $F(1, 141) = 4.92, p = .03$. Participants who had read about an intentional threat were more likely to agree that Lisa deserved to be hit than when the threat was unintentional (see Table 1). There was no effect on extreme blame as a result of relationship type, and there was no interaction.

Table 1

Significant Effects for Intentional and Unintentional Threat

	Intentional Mean	Unintentional Mean
Lisa deserved to be hit	1.60 (.11)	1.23 (.12)
It is at least somewhat justifiable that Jack hit Lisa	1.79 (.131)	1.28 (.138)
Sympathy towards Lisa	4.85 (1.52)	6.288 (.16)
Sympathy towards Jack	2.69 (.139)	1.79 (.146)

* Standard Errors are in parentheses below each mean value.

Partial blame was measured by agreement with the statement “Lisa was somewhat at fault for getting hit.” There was a main effect of intentionality that was qualified by a significant interaction, $F(1, 137) = 3.62, p = .059$. As predicted, for intentional violations, participants who perceived the relationship as egalitarian were just as likely to blame Lisa as were participants who perceived the relationship as traditional (see Table 2). However, contrary to predictions, when it came to unintentional violations, participants who perceived the relationship as egalitarian were more likely to blame Lisa than participants who perceived the relationship as traditional (see Table 2).

Table 2
Interaction Between Type of Relationship and Intentionality on Participants’ Agreement with the Statement “Lisa was somewhat at fault for getting hit.”

	Traditional	Egalitarian
	Mean	Mean
Intentional	2.66 ^a (.22)	2.32 ^a (.26)
Unintentional	1.15 ^c (.25)	1.75 ^b (.25)

* Standard Errors are in parentheses below each mean value.
* Means values with different superscripts are significantly different.

An ANOVA was also conducted for measures of extreme and partial justification for Jack’s actions. Extreme justification was measured by agreement with the statement, “Jack was justified in hitting Lisa.” There were no significant main effects nor was there an interaction. Participants tended to mostly disagree with this statement regardless of the couple’s relationship type. I measured partial justification for Jack’s actions by agreement with the statement, “It is at least somewhat justifiable that Jack hit Lisa.” There was a significant main effect involving the type of threat, $F(1, 140) = 7.095, p = .009$. Participants were slightly more likely to find the action justifiable if the threat was intentional than when it was unintentional (see Table 1).

I also measured participants’ general feelings towards Jack and Lisa. Participants rated how much anger and sympathy they had towards both Lisa and Jack. Anger was reverse scored and combined with sympathy to form a sympathy scale (high numbers indicate more sympathy). There was a significant main effect of intentionality on feelings towards Lisa, $F(1, 140) = 42.36, p = .001$. Participants were more sympathetic towards Lisa when the threat was unintentional than when it was intentional (see Table 1). There was a main effect of intentionality on feelings of

sympathy for Jack, $F(1, 140) = 20.24, p = .001$. Participants felt more sympathy toward Jack when the threat was intentional than when it was unintentional (see Table 1).

Discussion

This study examined the role of traditional gender values and perceived threat on acceptance of dating violence. Specifically I wanted to see if being in a traditional relationship would make outsiders more likely to be accepting of intimate partner violence. Also, I wanted to see if the intentional threat to a masculine gender role would lead to more acceptance of interpersonal violence. I found that the type of relationship did not matter nearly as much as the type of threat. Participants were more likely to place blame on Lisa and justify Jack’s actions when the threat was seen as intentional. This finding relates to Crick & Dodge’s (1994) description of hostile attribution bias. People who have a hostile attribution bias tend to interpret negative behavior as intentional and hostile and are more likely to respond with aggression. It appears that perceiving an interaction in which another’s behavior could be seen as hostile (i.e., intentional) makes observers more likely to legitimize or justify an aggressive response from the person who was threatened. In the vignettes that described Lisa’s threat as intentional, hostile attributions were made, and it was considered more acceptable for Jack to respond by hitting Lisa. In this situation Lisa was also more likely to be blamed somewhat for getting hit.

This finding may explain why intimate partner violence continues to be prevalent in relationships. If outside social support systems perceive the victim as even somewhat responsible for the violent acts against them, the victim may be reluctant to leave the relationship. Such outside supports may legitimize the violence and place blame on the victim if they feel that she intentionally provoked the violent act. In a study by Johnson, Frattaroli, Campell, Wright, Pearson-Fields, & Cheng (2005), teens were interviewed about their perceptions, experiences, and consequences of violence. In discussions of witnessing intimate partner violence, both sexes tended to have beliefs that lead to blaming the victim blaming and accepting violence against women when the woman appeared to have done something to antagonize her partner. Participants justified the violent acts by saying “sometimes the girl would try and make the boy hit her,” or that, “Some women do not know how to be quiet,” when they felt the woman intentionally initiated the conflict because of something she said (Johnson et al., 1005, p.176).

I also found contradictory results pertaining to relationship type. Participants perceiving transgressions in an egalitarian relationship were more likely to blame the woman even when the

transgression was unintentional. This may be due to expectancy violation, where people see personal affronts to an equal partner as more of a violation of relationship values than affronts to a dominant partner (as is the case in a traditional relationship). However, this effect may also be due to the fact that our sample consisted mainly of young people who may not value traditional relationships and may in fact see them as oppressive toward women, and thus may justify her attempts to assert herself in the relationship.

Future studies should be aimed replicating the present findings using a non-college population. Our sample of young college students may not practice or endorse traditional relationship values to the same degree as a non-college, community population. An older population may conform to more traditional gender roles and may be more accepting of violence when those roles are violated. Also, the present study included many more female than male participants. This too, could have influence the perceptions and valuations of the egalitarian relationship structure over a traditional one. In the future, it would be important to include more male participants to obtain a more gender-balanced sample.

In summary, the present study shows that perceived intentionality has a significant effect on the acceptance of intimate violence, regardless of whether the relationship type (traditional or egalitarian) would seem to support such acts and despite the fact that the participants (majority being college women) should be the most opposed to dating violence. These findings suggest that perceived intentionality may figure prominently in creating prevention programs for intimate partner violence. In prevention programs, it would be important to undo victim-blaming attributions and instead stress the importance of having peers and social support systems speak out against the witnessed violence and help the person being victimized leave the violent situation.

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Childhood Experience and Pro-Environmental Behavior

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Abstract This study investigates correlates of pro-environmental behavior in light of prior research that suggests that even though environmental education has increased over the past several decades, pro-environmental behavior has decreased. College students completed an on-line survey that assessed their environmental attitudes and behavior, as well as their environmental knowledge and background demographics. The results indicate that concern for an upcoming ecological crisis, a biocentric perspective, and childhood experiences in nature are more important than environmental knowledge in explaining pro-environmental behavior. This could potentially change the way environmental education is taught: By including more time outdoors during classroom instruction, students may later adopt a more pro-environmental lifestyle.

Introduction

Concern for the environment currently is much discussed in the news media and academic journals. Many feel that we are approaching a tipping point in our environment and that something needs to be done before we, and our descendants, not only miss out on the beauty of nature but also suffer from the lack of a healthy environment. Many people are aware of environmental issues and want to be pro-environmental, altering their lifestyles to help benefit or at least not harm nature. Despite this and several decades of increasing efforts in environmental education, there is evidence of a decline in pro-environmental behaviors in American teens over the past 30 years (Wray-Lake, 2009). The literature suggests that there is an association between environmental behavior and environmental attitudes (Bamberg and Moser, 2006), but it is not enough just to educate people about environmental concerns (Kollmuss & Agyeman, 2002).

Since 1978 scientists have used the New Ecological Paradigm (NEP) survey to measure peoples' ecological worldview. The NEP was recently updated to include more current ecological perspectives. Overall, the NEP measures inclination towards pro-environmental attitudes (Dunlap, 1978; Dunlap et al., 2000, Dunlap, 2008). A particular interest of this study is whether the person is anthropocentric or biocentric. Biocentric describes the perspective of those who feel that they are a part of nature - another living organism in a very complex system. In contrast, anthropocentric means that people believe that they are separate from the environment and don't consider themselves part of it.

This study examines the relationship between college students' self-reported likelihood to engage in pro-environmental behavior and their environmental worldview as measured by the NEP. In addition, it examines the impact of other potential attributes on behavior. These attributes include gender, year in school, knowledge of environmental issues, where the students grew up, and childhood experiences with nature. I hypothesize that childhood experiences in nature would be the strongest predictor of pro-environmental behavior. Furthermore, I expect knowledge and environmental attitudes to also be important in explaining pro-environmental behavior.

Methods

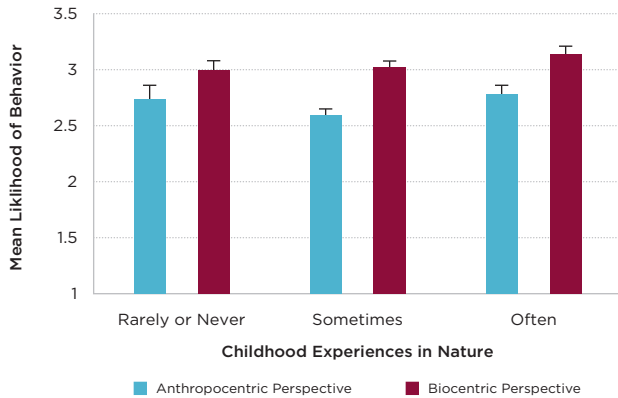
The survey was administered online to students from the DePaul University psychology participant pool. It included the 15 items of the NEP as well as background information on where the participant grew up as well as his or her experience in nature as a child. Open-ended questions were asked to evaluate each person's current environmental knowledge. Finally, participants were asked to indicate how often they were likely to engage in nine different environmental behaviors.

The NEP is a set of 15 statements designed to measure subjects' the pro-environmental worldview. Subjects respond to each statement by indicating how much they agree or disagree with it. The NEP has five dimensions, each identified with three of the survey statements. The five dimensions are: reality of limits to growth, biocentric perspective, fragility of nature's balance, rejection of exemptionism, and possibility of an eco-crisis (Dunlap et al., 2000). Pro-environmental behavior and environmental knowledge were quantified as a composite score of multiple items

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Figure 1

Effect of ecological perspective and childhood experience on pro-environmental behavior



on the survey. Pro-environmental behavior was the average of a student's likelihood of engaging in each of nine activities over the course of a year. Behaviors included recycling, turning off lights, and volunteering or donating money to support environmental causes. Environmental knowledge was assessed through a series of basic ecological questions and totaling correct responses. Data were analyzed by analysis of variance, chi-square and multiple regressions using SPSS.

Results

Of the 385 subjects surveyed, 70.6% were women and 57% were freshmen. Most grew up in the suburbs (63%), while 27% grew up in an urban environment. A minority classified themselves as having no or little environmental exposure as a child (19%). Students categorized themselves as being somewhat likely to act in a pro-environmental way over the next year (mean=2.92 +0.57 SD; scale 1-4: not likely to very likely), indicating the greatest likelihood to participate in recycling (mean= 3.53) and the least likelihood to donate money (mean= 2.57). Students tended to have a slightly pro-environmental worldview with female students slightly higher than male students (female NEP average =3.58, male NEP average = 3.41, $t(381)=2.717, p=0.007$). Males and females did not differ in their measures of environmental knowledge, in both cases averaging around 67% of the maximum knowledge score.

Using stepwise multiple regression, I looked which variables being measured (five components of the NEP, gender, childhood experience, where the subject grew up, sophistication of open-ended answers, and ecological knowledge) best explained variation in environmental behavior. Four of these variables together explained 32% of the variation in pro-environmental behavior.

Table 1

Dependent Variable: Average Pro-Environmental Behavior

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Source	SS	df	MS	F	p
Biocentric	11.148	1	11.148	38.585	0.000
Childhood Experience	1.980	2	0.990	3.427	0.034
Interaction	0.230	2	0.115	0.397	0.672
Error	108.630	376	0.288910194		
Total	3374.370	382			

The best predictor for pro-environmental behavior was the NEP crisis, which explained 24% of the variation ($p<0.0001$). The next best predictor was the NEP biocentric perspective, which explained an additional 4.5% ($p<0.0001$). The third significant predictor was childhood experiences with nature, which explained an additional 1.5% ($p=0.009$). Lastly, environmental knowledge explained an additional 1% ($p=0.017$). All the values were positively associated.

I used an Analysis of Variance (Table 1) to explore the impact of a biocentric perspective and childhood experience in nature. The results showed that a biocentric perspective was more likely to produce pro-environmental behavior than an anthropocentric perspective (Figure 1) and that students who had the most childhood experience with nature were the most likely to engage in pro-environmental behavior. This was true for all students, both anthropocentric and biocentric (Figure 1).

Discussion

The purpose of this study was to see what factors explain pro-environmental behavior in college students. The best predictor of pro-environmental behavior was whether students felt there was an imminent ecological crisis (NEP crisis). This result is not surprising; concern for an upcoming crisis should be a strong motivator for corrective behavior. The second predictor of pro-environmental behavior was peoples' belief that they are a part of nature (NEP biocentric). The third predictor of pro-environmental behavior was childhood experience with nature. This was more important than knowledge about nature, but not as important as the previously stated factors. Knowledge about nature was a significant predictor, but the least important in explaining pro-

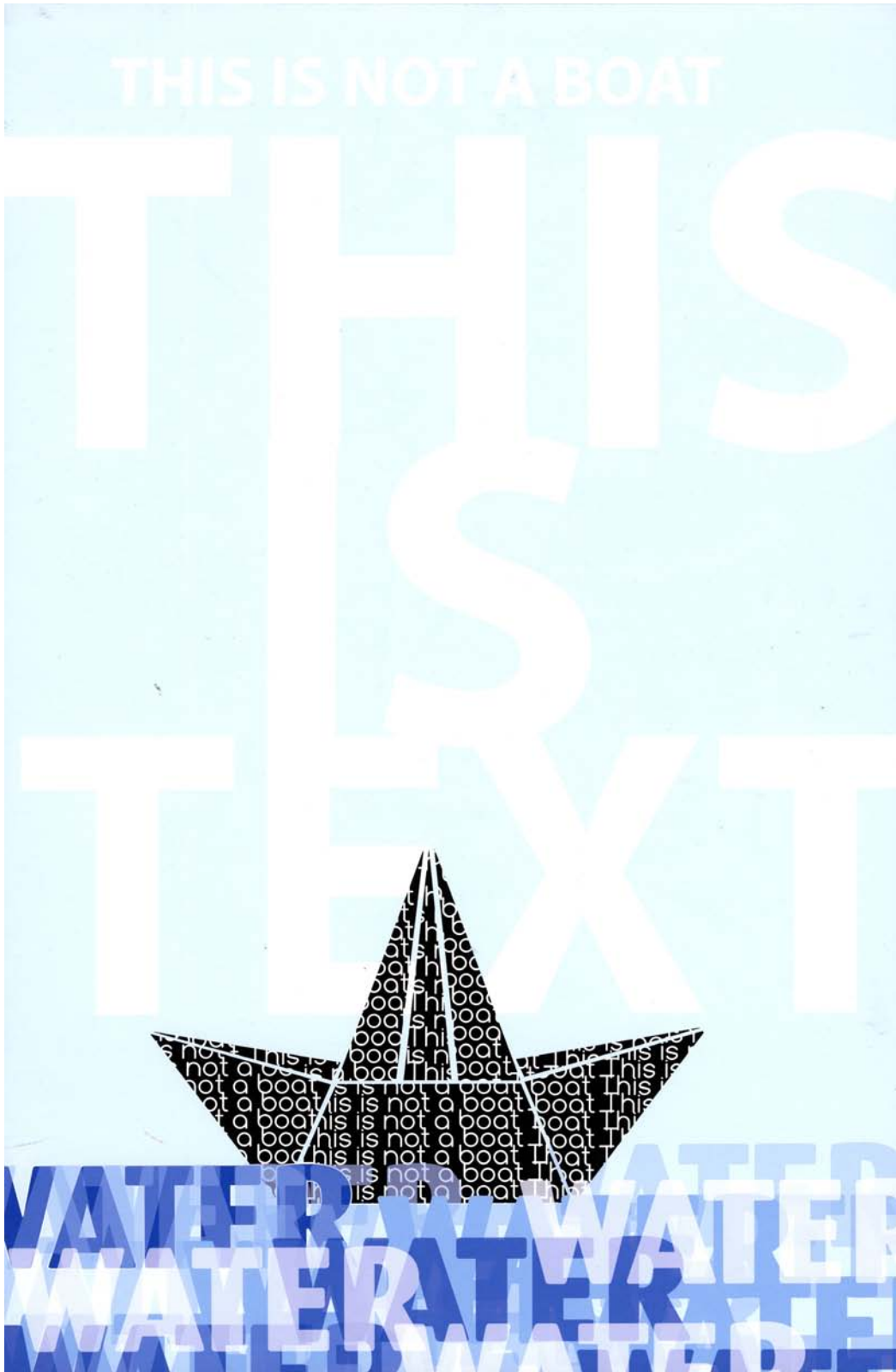
environmental behavior. Looking at the order of the predictors of pro-environmental behavior, it can be concluded that feelings about nature provide a greater effect on pro-environmental behavior than knowledge does.

Furthermore, the data show that childhood experiences, not the location (suburban, urban, or rural) where participants grew up, explain pro-environmental behavior. Because of the increasing urbanization of the world's population, this means that people growing up in an urban setting can still demonstrate a pro-environmental lifestyle as long as they have had early experiences in nature such as hiking, fishing, camping, etc. This study did not indicate what types of experiences were most powerful in promoting future pro-environmental behavior.

Our study showed that the feeling of an ecological crisis and the feeling of being part of the ecosystem are more important in explaining pro-environmental behavior than knowledge. It is likely that childhood exposure to nature provides an emotional attachment to the environment and may be intimately connected to an environmental worldview. A biocentric perspective is likely to be developed through childhood experience with nature. People exposed to nature at an early age tend to care more for it, to be more pro-environmental and wish to reduce their impact on the environment. This is an important finding. Many people turn to environmental education to increase environmental attitudes and behaviors. According to our data, children should be exposed to the environment more often in order for them to care more about the environment. Furthermore, even people who are anthropocentric tend to be more prone to acting pro-environmentally if they have had frequent childhood experiences with nature. This can potentially change the way environmental education is taught, which can lead to students' spending more time outdoors and later adopting a more pro-environmental lifestyle.

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Marco Antonio Cortes
This is Not a Boat
Print with Illustration

The Impact of Different Types of Environmental Messages on Dormitory Residents' Energy Conservation Behavior

Marian Vernon*

Abstract

I conducted a weeklong energy-saving competition among the residents of DePaul's University Hall dormitory to determine what messages are most effective in changing environmental attitudes and behaviors. I studied the use of feedback and incentives to reduce consumption, environmental education, and complementary injunctive and descriptive norms to influence people's attitudes towards the environment. Two floors were exposed to environmental education messages, and the other two floors were exposed to complementary injunctive and descriptive normative messages. I found that environmental education was more successful in changing environmental behaviors, and hypothesize that normative messages may not be effective when presented to groups of individuals with strong friendships and daily interactions. Due to the low number of replicates, further research is necessary to test this alternative hypothesis.

Introduction

Although surveys suggest that people in the United States are aware of environmental problems such as global warming, pollution, and resource depletion, fewer people actually behave and act in environmentally friendly ways (Pelletier et al., 1997). One question that environmental thinkers, psychologists, and sociologists have in common is determining the most effective ways of motivating people to change their behaviors and actions permanently. College dormitories can be used to test different methods of motivating residents to conserve energy. Already, numerous colleges across the U.S. have begun to implement energy-savings competitions between college dormitory residents, using a variety of methods to encourage residents to save electricity. In this research project, I designed an energy-savings competition among the residents of DePaul's University Hall dormitory, and employed two different methods in order to determine which was more effective in changing environmental attitudes and behaviors in this age group.

Oberlin College has implemented several energy-savings competitions among numerous on-campus resident halls. Each residence hall had a computer monitor in the building's lobby, which showed the amount of energy being used by each hall at that moment and how much energy had been saved over the course of the competition. The introduction of this live informational feedback resulted in a 32% reduction in residents' electricity use when combined with incentives, thus suggesting that

feedback systems combined with education and incentives can motivate and empower college students to reduce their resource use in dormitories (Petersen, et. al. 2007). One of the Oberlin hypotheses suggests that if dormitory residents are made aware of how their current resource use contributes to problems such as global warming, pollution, and depletion of resources, they may feel motivated by moral and ethical reasons to reduce consumption. This emphasizes the mainstream idea that people will not be motivated to change their lifestyles unless they understand the connection between their behavior and subsequent environmental consequences; informational feedback technology should therefore increase awareness by providing a visual representation of resource consumption and in turn motivate residents to decrease their energy use. However, this usually only works with residents who are already concerned about environmental issues but never employed consumption practices (Petersen et. al., 2007). Additionally, once incentives are removed, behavior returns to baseline levels (Petersen et. al., 2007).

Researchers today have begun to approach this problem from a new direction by investigating how the behaviors of individuals and the messages they are exposed to are related (Marans and Edelman, 2010; Cialdini, 2003). Social researcher Robert Cialdini has observed that when people try to address social problems, they make statements to the effect of, "many people are doing thing X which is creating many problems" (Cialdini, 2003, italics mine). The message received is that although the behavior is bad, it is what most people are doing. This then gives people little incentive to change their behavior. Cialdini (2003) identified injunctive and descriptive norms that influence per-

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ceptions and behaviors. Injunctive norms involve perceptions of which behaviors are typically approved or disapproved; descriptive norms involve perceptions of which behaviors are typically performed. Both norms impact human behavior and action, and most people do what is both socially approved and socially popular. Therefore, it is best to send messages that encourage a particular action, such as conserving electricity, while stating in the same message that the majority of people participate in the this action, which in this example would be conserving electricity.

In designing and implementing DePaul's energy-saving competition, I researched what type of message was more effective at motivating students to decrease their energy usage during the weeklong competition. I used two types of messages: environmental education messages and complementary descriptive and injunctive normative messages. To study the effects these different methods have on the resource consumption of residents, I varied which students would be exposed to each method. I hypothesized that the use of complementary descriptive and injunctive normative messages would be a more effective strategy than environmental education in fostering a reduction in energy usage by students.

Materials and Methods

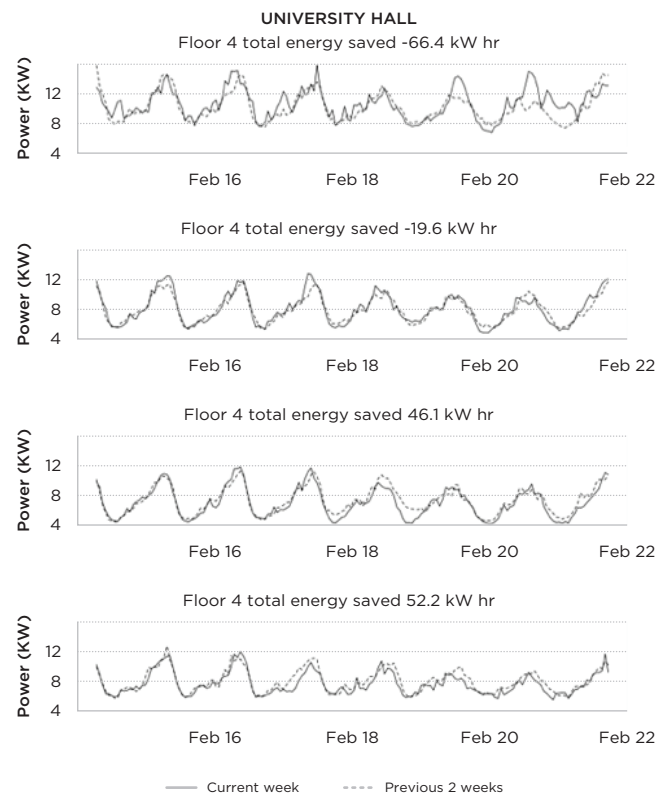
DePaul's University Hall dormitory is a four-story residential building that was constructed in 1986. The rooms are semi-suites, with single rooms that host one, two, or three residents. Every two rooms share an adjacent bathroom. The central laundry room is located in the basement of the building, and each floor has a full kitchen, lounge, and study room. Each room contains an individually controlled air-conditioning unit. The first floor has fewer residents than the other three floors, and the first floor also has a permanent resident with his own individual living area. During the fall of 2008, 12 power monitors were installed in the building. Each monitor measures one 3-phase electrical panel, and there are three electrical panels per floor. Power measurements are recorded every 15 minutes, and an automated script collects the data hourly at 35 minutes past the hour. During the competition, the current power usage was compared to the same hour averaged over the previous two weeks. If the current power usage was greater than in the previous weeks, the automated script showed a negative number in energy usage.

I designed several bulletin boards containing either environmental education (educational) or complementary descriptive and injunctive normative messages (behavioral). I divided these bulletin boards between the four floors of University Hall dormitory. I placed the behavioral bulletin boards on Floors 3 and 4 to emphasize to those residents that all the other students in the

dormitory cared about environmental issues and had participated in the competition the previous quarter. I put the educational bulletin boards on Floors 1 and 2 to provide them with environmental information and education. I also distributed fliers about the competition to each resident. For Floors 1 and 2, I distributed fliers offering environmental information and education; in particular, these fliers listed facts about coal pollution in Chicago and how this pollution contributes to numerous health problems for Chicago residents. For Floors 3 and 4, I distributed fliers that emphasized complementary injunctive and descriptive normative messages. These fliers stated that all the residents in the dormitory had shown that they really care about the environment through their participation in the previous energy savings competition and that they should therefore participate in the upcoming competition. All the fliers stated that the winning floor would receive a party, included a website address where they could view their floor's energy consumption in comparison to a baseline (las.depaul.edu/powerproject), and also advised the residents to look at the bulletin boards on their floors for more information about the competition.

Figure 1

Week of the Competition (Week 59) Compared to the Previous 2 Weeks (Weeks 57, 58)



Results

Figure 1 shows the energy usage by floor during the week of the competition (Week 59). The black line represents the current usage of the week in comparison to the dotted line, which represents the baseline energy usage. The baseline was the average energy usage of the previous two weeks prior to the competition (Weeks 57 and 58). One trend that can be observed is that Floors 1 and 2, whose residents were exposed to the educational fliers and bulletin boards, saved energy during the competition while Floors 3 and 4, where students were exposed to the behavioral norm fliers and bulletin boards, used more energy than in previous weeks.

Table 1 compares the energy saved by each floor the week of the competition in comparison to the energy saved the week after the competition, compared to the same baseline. Floor 1’s energy usage the week after the competition is very similar to the baseline conditions, whereas Floor 2’s energy usage the week after the competition showed additional savings. Floors 3 and 4 showed an increase in energy usage for both the week of the competition and the week after the competition when compared to that common baseline.

Discussion

Floors 1 and 2 both decreased their energy usage, while Floors 3 and 4 used more energy than in previous weeks. This evidence does not support the original hypothesis, which stated that by exposing Floors 3 and 4 to complementary descriptive and injunctive normative messages, the students would be motivated to reduce their energy consumption due to their desire to fit in with this socially acceptable form of behavior, saving more energy than the other floors. Instead, Floors 1 and 2, which exposed residents to informational and educational messages about the environment, conserved more energy during the competition. The week after the competition, Floor 1’s energy usage returned to the baseline with very slight energy savings. This suggests that

with the removal of incentives, many students abandoned their energy-saving practices. However, Floor 2’s energy savings continued the week after the competition, suggesting that the students continued their energy-saving practices and behaviors even with the removal of incentives. Floors 3 and 4 continued to use more energy than they had previously.

While there appears to be a correlation between the two treatment types and the outcome of the competition, a variety of other reasons could explain the results. They may be due to methodological issues, such as a low number of replications and the variability of the heating and cooling system of the building. If these methodological issues affected the results in a profound way, the initial hypothesis may still be supported. However, if the results are not due to chance, then the initial hypothesis should be rejected and alternative hypotheses explored. In Cialdini’s research on hotel guests, the groups were not directly influenced by other people in the same environment. While they were exposed to messages that both emphasized that conservation behaviors are socially acceptable and that a majority of people participate in these environmentally conscious behaviors and actions, hotel guests do not often interact with one another in a way that could profoundly alter their perceptions and behaviors. Therefore, the only real influence on their behaviors and actions was the complementary injunctive and descriptive norms used by the researchers and their own individual perceptions about environmental issues.

I hypothesize that since the dormitory residents in this particular study live with each other and interact on a daily basis, perhaps participating in classes, sports, and other activities together, the students may have strong bonds with one another and may influence one another’s decisions. These factors may have created an environment in the dormitory qualitatively different than the environments in Cialdini’s study. In our study, students may have felt external pressures from the other residents to do what was considered socially acceptable, which may have been in direct conflict with the norms the complementary injunctive and descriptive messages were trying to convey.

Floors 1 and 2 were exposed to messages that discussed environmental issues in their immediate environment and throughout the world. A researcher at University of California, Berkeley recently found that environmental education changed the behaviors of environmentally conscious individuals who had not previously practiced environmental conservation (Kitajima, 2009). Additionally, empathy may have played a part in why students responded to the educational fliers. Some information provided to the residents included facts about pollution in the Chicagoland area that has caused many health problems for the residents liv-

Table 1
Week of the Competition Compared to Week After the Competition

Floor Number	Energy saved week of competition (in kwh)	Energy saved week after the competition (in kwh)
Floor 1	52.2	5.5
Floor 2	46.1	44.7
Floor 3	-19.6	-39.2
Floor 4	-66.4	-95.6

ing in close proximity to coal plants; many neighborhoods located near the plants are demographically high minority low income. This information may have stimulated an empathetic response by the residents, giving them moral and ethical reasons to reduce their electricity consumption. The use of complementary descriptive and injunctive norms emphasizes personal behaviors and actions when compared to the socially acceptable behaviors of the group a person identifies with, whereas the use of environmental education in eliciting an empathetic response focuses more on the individual level. Our findings suggest that the latter may be more effective in changing individuals' attitudes in a tight-knit group setting.

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Synchronizing a System of Coupled Oscillators

Brent Allen May Jarvis*

Abstract The behavior of a system of coupled oscillators is examined using numerical techniques. This system can be understood as a collection of masses connected by springs which are confined to move along the rim of a circle. One oscillator in this system was subjected to a periodic driving force in an attempt to synchronize the system. The possible paths toward synchronization have been explored through graphical analysis. All data has been generated through computer simulations.

Introduction

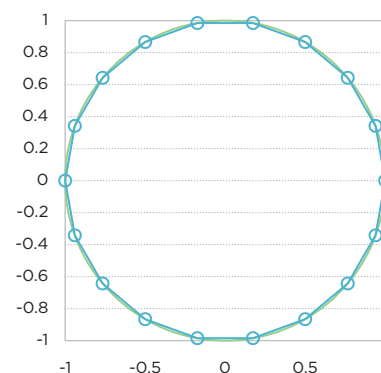
Understanding the dynamics of coupled oscillator systems is extremely important in many physical systems. An oscillator is anything that has some sort of periodic behavior. A pendulum, spring, or even a child on a swing can be thought of as an oscillator. Numerous examples of oscillators and synchronization can be found in all scientific fields. For example, the synchronization of fireflies in Southeast Asia can be modeled as a coupled oscillator system. The fireflies pulse periodically as each firefly attempts to match its neighbor's rhythm. This results in the entire group flashing on and off in unison.¹ Another place coupled oscillators are at work is within the human intestine. The cilia, little hairs lining the bowel, move back and forth in unison transporting food through our bodies. The ability of systems to synchronize and how to force them to synchronize have become increasingly important over the past few years as more networks have been recognized to behave like coupled oscillators. The problem is that the dynamics of coupled oscillator systems becomes very complicated as the number of oscillators and types of connections increase.

For this project the oscillators can be envisioned as masses connected by springs. Each mass is connected to two others. The masses are confined to sliding along the edge of a circle. Keep in mind that the masses and springs are allowed to slide past and through each other without any physical contact. The springs pull at each mass in an effort to shrink to zero length. Hence, when all the oscillators are at the same location in the circle there are no stresses in the network and each oscillator is behaving exactly the same. This is the configuration which corresponds to synchronization. Coincidentally, this means that the potential energy of the system has gone to zero.

In this experiment we begin the system in the most stable unsynchronized state. This equilibrium corresponds to the oscillators being evenly spaced around the circle. This arrangement is shown in Figure 1 where 18 oscillators, shown in blue, are evenly spaced around the circle. The blue lines illustrate the connections between each oscillator. The green line simply shows the circle to which the system is confined. It is easy to see that this configuration is symmetric. Due to its symmetry all the forces between the oscillators are balanced, resulting in a state of stable equilibrium. In an effort to synchronize the network, a periodic driving force was added to one of the oscillators in the circle. The driving force was turned on for one and a half periods and then the system was allowed to equilibrate. By testing different combinations of frequency and amplitude, I hoped to develop a systematic method for synchronizing this system. A relied on a computer program to

Figure 1

This picture demonstrates the equilibrium position of the oscillators beginning evenly spaced throughout the circle. All of the circles represent masses and the blue lines springs.



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1. Strogatz, 103-106

run simulations using different frequencies, amplitudes, number of oscillators and connections using MATLAB.

Theory

Using Lagrangian mechanics we can derive the equations of motion for this system. This begins by determining the potential energy of the system which is given by

$$U = \sum_{i=1}^n kr^2(1 - \cos(\phi_i - \phi_{i+1}))$$

where ϕ_i is the angle of oscillator i , k is the spring constant, r is the radius of the circle, i is the index of the oscillator and spans $1, 2, 3, \dots, n$, and n is the number of oscillators. In this project the number of oscillators was confined to 18. It can be seen that $U=0$ if all the oscillators have the same angle so that $\phi_i = \phi_{i+1}$. Note that i refers to an index, not a position of the oscillator, thus oscillators 1 and 2 are not necessarily next to each other on the circle. From the potential energy we can derive the acceleration of each oscillator. This is given by

$$\ddot{\phi}_i = \frac{k}{m}(\sin(\phi_{i+1} - \phi_i) + \sin(\phi_{i-1} - \phi_i))$$

where $\ddot{\phi}_i$ is the acceleration of oscillator i . The sine terms represent the distance from one oscillator to the next. This equation is periodic mod n , or in other words, when n is the same as i then $i+1=1$, causing the last oscillator to become coupled to the first. Figure 2 shows a general configuration of four oscillators. The angles of the first and fourth oscillators are shown in black and labeled ϕ_1 and ϕ_2 respectively. The forces between each oscillator are shown in red. The relative length of the double-sided arrow illustrates the magnitude of the force between the two oscillators. Second derivative equations can become cumbersome because they allow oscillations in the system to exist which can cause chaotic effects. In order to simplify the system, we compare it to the damped harmonic oscillator, or a spring with friction, which has the form

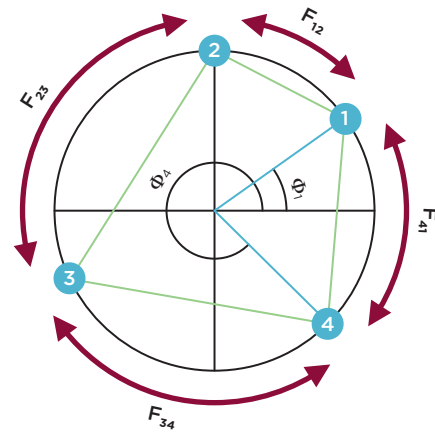
$$\ddot{\phi}_i + \beta\dot{\phi}_i + \frac{k}{m}\phi_i = 0$$

where $\dot{\phi}_i$ is the velocity of the oscillator at position ϕ_i and β is some damping or frictional constant. If we set the radius of the circle, spring constant, and mass all to unity and let $\beta \gg 1$. then by analogy to Eq. 2, we have²

$$\dot{\phi}_i = \frac{1}{\beta}(\sin(\phi_{i+1} - \phi_i) - \sin(\phi_{i-1} - \phi_i))$$

Figure 2

This figure demonstrates four oscillators connected by pale green lines. The angles of the oscillator 1 and 4 are shown by black traces around the circle. The forces are shown in red on the outside of the circle where F_{12} corresponds to the force between oscillators 1 and 2 the others similarly.



This is the system being inspected in this project. It is simpler than Eq. 2 because this is a first order system. This means that the system can never have oscillatory equilibrium states due to the damping. In other words, the oscillators beginning at some random configuration will eventually settle down into some resting position. This is guaranteed because the system is overdamped. That is to say, there is so much friction in the system that the springs cannot vibrate back and forth. In fact the only freedom they have is to pull the masses toward their rest length, which as stated is zero. For just two masses connected by a single spring this would result in their collision. Beginning at some random configuration, it is extremely difficult to tell whether or not a system will synchronize or end up at some other equilibrium. Since an equilibrium is inevitable, we can begin the system at an equilibrium instead of a random initial configuration without any adverse effects.

The equilibrium states for this network can be determined as well. The most intuitive of these corresponds to the state where the oscillators are evenly spaced around the circle. This is given by

$$\phi_i = \frac{i\omega 2\pi}{n}$$

2. Strogatz, S.H. and D.A. Wiley

where F is the winding number corresponding to how many times the oscillators are wrapped around the circle. Other equilibrium states can also be obtained for this system. Instead of equally spaced oscillators, a star, or some other shape, could provide the balance the system requires to remain stationary. These equilibria are extremely unstable however, so forcing the system out of this state is extremely easy and uninteresting. In this project, $w=1$, so that the oscillators begin evenly spaced about the circle which is a very stable arrangement. This configuration is shown in Figure 1.

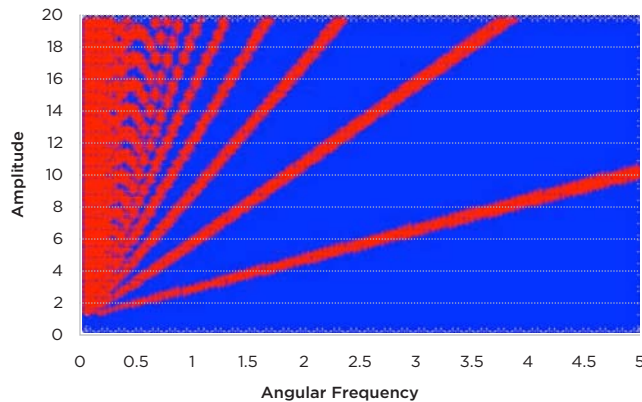
Once the oscillators had been spaced equally, a driving force was added to the first oscillator, $i=1$, so that Eq. 4 or the first oscillator looks like

$$\dot{\phi}_1 = \sin(\phi_2 - \phi_1) - \sin(\phi_n - \phi_1) + A \sin(\omega t)$$

where A is the amplitude of the driving force, ω is the angular frequency, and t is time. The driving force was only attached to one oscillator because it was hoped that this would reduce the number of paths toward synchronization. It was also thought that in application it would be easier to perturb one oscillator rather than two in the same way. Because the network is symmetric, it is a matter of convenience that the first oscillator was chosen to be the driven oscillator. The perturbation described in Eq. 6 pushes the oscillator back and forth in an effort to cause the other oscillators to fall into synchronization. Once the system is near synchronization it will become attracted to that state naturally because all of the springs want to have zero length.

Figure 3

This plot shows the frequencies and amplitudes over which the experiment was conducted. The blue circles correspond to the total data set. The red stars represent which frequencies and amplitudes that synchronized the system.



Methodology

A MATLAB program was built using the Graphical User Interface Development Environment software package. The Runge Kutta fourth order method³ was implemented to solve Eq. 4. A data generating program was built to automatically run the driving force over different frequencies and amplitudes. A data analysis program was written to load all the data and determine which driving frequencies and amplitudes cause the system to synchronize. Eq. 1 was used during this process to determine whether the system had synchronized. If $U < 0.005$, then the system was assumed to have synchronized. The lowest equilibrium state above this has a potential energy of 0.5428, so we are safe in using this assumption.

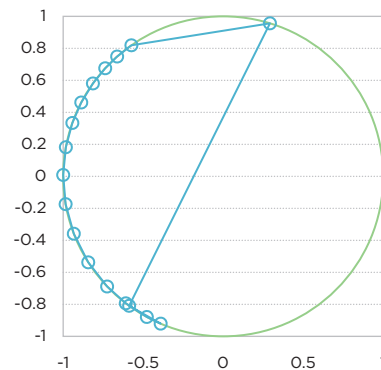
Data Analysis

Figure 3 shows the amplitudes and frequencies that caused equilibrium transitions. The red points represent the respective amplitudes and frequencies that caused equilibrium transitions whereas the blue circles illustrate the entire data set. This plot clearly illustrates that specific regions enable the system to be driven to synchronization. A bifurcation between high and low frequencies is presumed to occur at $\omega \approx .25$. It is here that some frequencies stop causing the system to synchronize.

Low frequencies produce the most populated region of the graph. This is because the speed at which the driving force changes direction is slower. This allows neighboring oscillators to feel the effects of the oscillator being driven around the circle, which

Figure 4

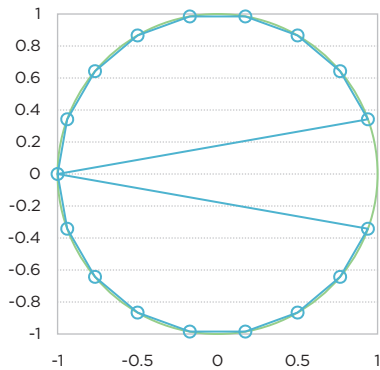
This shows how lower frequencies can influence the majority of the oscillators driving them together. The driven oscillator is at the top right corner. The asymmetric grouping of the oscillators will pull them together.



³ Garcia, 77-93

Figure 5

This illustrates a position where the driven oscillator could stop and draw the rest of the other oscillators in toward synchronization without perturbation to the other oscillators. Note that at the position $(-1,0)$ there are two oscillators. These two draw the rest of the oscillators towards them and synchronize the network.



in turn causes more and more oscillators to begin to move. Eventually, a group effect takes hold where a number of the oscillators are moving together until they synchronize, no matter where the driven oscillator is when the driving force is turned off. This can be seen in Figure 4 where the driven oscillator is at the top of the circle, separated from the group. The rest of the oscillators have begun to cluster together along one side of the circle. When the driving force is turned off, the driven oscillator will be pulled toward the others, resulting in synchronization. During low frequency perturbation, it is often observed that the oscillators will line up behind the driven oscillator like links on a chain. Imagine someone dragging a chain by the center link with the rest of it trailing behind him or her. The links not being held will align with each other. This is what happens when the system unwraps itself from the circle as the driving force is applied. Once lined up in this manner, it has been impossible to unalign the oscillators driving only one oscillator.

At higher frequencies the group effect becomes greatly diminished. This is because the driven oscillator changes direction too quickly for any but those that are connected nearest to it to feel any effects. Synchronization at these frequencies results from the driven oscillator being in the correct location when the driving force is turned off. Figure 5 illustrates this point. This figure demonstrates an idealized outcome when high frequency driving is turned off. The driven oscillator simply pulls the rest of the network in towards synchronization without any resonant effect from the system as seen in the low frequency case. The driven oscillator has symmetric forces and so will not move, whereas the oscillators just above and below $(0,1)$ are subject to asymmetric forces, resulting in their movement. This causes the rest of the oscillators to fall together at $(0,-1)$. This path toward synchronization is the only type that has been observed for large frequency values.

Future Work

The different paths toward synchronization need to be investigated more thoroughly. Exactly where the bifurcation point is between low to high frequencies needs to be more precisely determined. This can be done by characterizing the response time for the system and by looking at the symmetry of the system over time. Another important feature to be explored is the effect of the final position of the driven oscillator. Depending on where it stops, the system may return to its previous unsynchronized state or fall toward synchronization.

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Femtosecond-to-Nanosecond Clocking Using a Double-Slit Optical Encoder

Jakub Kolacz and Abraham Burleigh*

Abstract We have recently completed the construction of a laser that generates ultrafast and intense pulses of light. Here we present the first measurements of this new laser system, along with a new technique for improving the time resolution of our measurements to ~ 1 femtosecond (10^{-15} second) while still recording the response of a material over nearly one nanosecond (10^{-9} second). With such intense pulses of light, it should be possible to generate transient strain inside materials via the transfer of light's momentum rather than the absorption of optical energy, which would open up new ways to manipulate matter without transferring thermal energy. Another application of the apparatus will be measurements of the earliest responses of materials to light. These properties are important in the creation of all-optical computers and future data storage technologies.

Introduction

When light reflects or transmits at an interface, momentum must be conserved. One consequence is that the medium may recoil during the interaction [1]. This can be thought of as like jumping onto a diving board and having it bend under your weight. For short pulses of light, this radiation pressure is expected to result directly in an impulsive strain wave inside a material, without generating any heat, the usual byproduct of laser-matter interaction.

In this paper we demonstrate a new technique that permits us to accurately control light pulses down to the femtosecond timescale where these radiation pressure effects should dominate, while still maintaining the ability to measure the acoustic response of a material that occurs over a time-period that is nearly six orders of magnitude longer. Figure 1 illustrates an overview of this process.

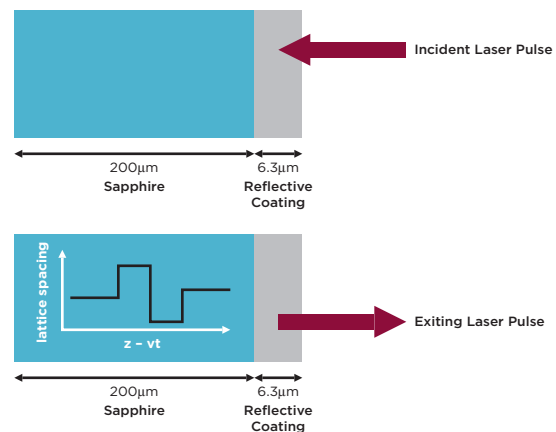
Methods

Radiation pressure is proportional to the intensity of light, or its energy per unit time and area. This is in contrast to conventional optical absorption, which depends only on energy. Therefore, to observe situations where the momentum of light predominates, a small amount of energy should be concentrated in both space and time.

To obtain such high intensities of light in a table-top laboratory, we constructed a Titanium:Sapphire laser from a kit (KM-

Figure 1

Example of ultrafast laser-induced radiation pressure. In the top figure, a femtosecond light pulse is focused onto a high-reflectivity mirror. Detectable radiation pressures require very short pulses of light (femtoseconds). In the lower figure, the light pulse is completely reflected, but the mirror recoils, producing a strain wave that propagates into the mirror substrate. This strain generation and propagation takes place over a few nanoseconds and is related to the speed of sound in the material.



Labs, Boulder, CO) that uses an intra-cavity optical nonlinearity to collapse all circulating laser photons into a single brief pulse. First, a continuously operating diode-pumped solid state laser (5 W, 532 nm Nd:YVO₄ “Verdi”, Coherent Inc., Santa Clara, CA) was focused into a 5 mm thick, Brewster angle-cut Titanium

* Advisor: Eric C. Landahl, Department of Physics. We acknowledge assistance from fellow students G. Jackson Williams, Joseph Marcus, Thomas McManus, and Michael Watson. This work was supported by the College of Liberal Arts and Sciences and also by an award from the Research Corporation for Science Advancement. aber_920@msn.com, urshpreason@hotmail.com

doped Sapphire crystal placed near the center of a folded Fabry-Perot cavity. This produces a nearly isotropic intense fluorescent emission that is peaked near an 800 nm wavelength. Steady lasing was obtained by feeding the fluorescence back through the cavity and then adjusting end mirrors for peak output power. The optical path contains a matched pair of prisms on precision translation stages with their direction of travel set perpendicular to the prism base. Their insertion angle is chosen for minimum deviation during translation. Short pulses were obtained by first detuning the alignment of the cavity so that the pumping 532 nm laser focus no longer coincided with the recalcitrant 800 nm laser external cavity mode, and then slightly perturbing one of the prisms. This perturbation quickly (within microseconds) collapsed into a short pulse. Further adjustment of cavity mirrors to encourage the pulsed mode of operation allowed the single pulse to bounce around inside the cavity for an arbitrarily long amount of time (up to one week).

Such short pulses of light are difficult to measure and therefore difficult to optimize. They are extremely fragile: transport through just a few millimeters of clear glass can double the pulse-width, thereby halving the intensity and any radiation pressure effects. This type of degradation, which is due to each wavelength that combine to form a short pulse travelling at different speeds, has been widely studied [2]. In particular, it is possible to pre-compensate for this wavelength dispersion by constructing a second, external-cavity matched prism pair. The prism pair inside the laser cavity serves to cancel out any dispersion from repeated trips through the Titanium: Sapphire Crystal while the external pair can be independently adjusted ahead of all downstream optical materials. Unfortunately, such adjustment requires the careful measurement of these pulses at the femtosecond level *in situ* with the actual experiment to be undertaken (to ensure that all dispersive materials up to the target material are actually accounted for). This time resolution is obtainable when measurements are in close proximity to the short pulse; however, several experimental difficulties must be overcome to simultaneously measure (and therefore generate) short pulses while simultaneously measuring over a time range nearly a million times longer.

Figure 2 shows our solution to this problem. A rapid-scanning delay arm is built from a DC electric motor that can provide nearly one nanosecond of delay in less than one second of measurement time. The non-delayed laser pulse induces some change in the test material and the delayed pulse probes these changes. Rapid delay scanning is necessary to avoid long-term drifts in lengthy measurements and permit averaging of multiple scans to improve the signal-to-noise ratio. The major difficulty with this approach is scan-to-scan variability in the instantaneous

Figure 2

Optical layout of the femtosecond-to-nanosecond clocking apparatus. The rapid scanning delay stage follows an external prism compressor. The speed of the delay stage is measured by a second laser on each scan.

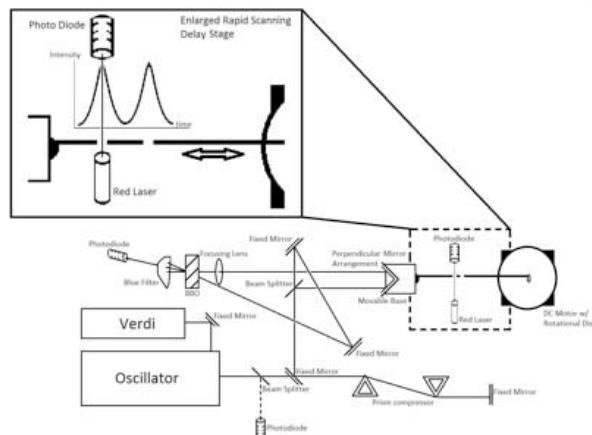
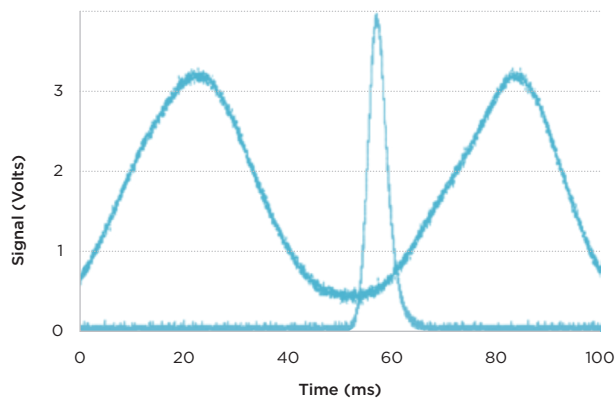


Figure 3

The double-slit pattern forms an optical encoder on the double-peaked oscilloscope trace. The temporal overlap of the original and delayed laser pulses shown in the central trace is used to determine the pulse duration

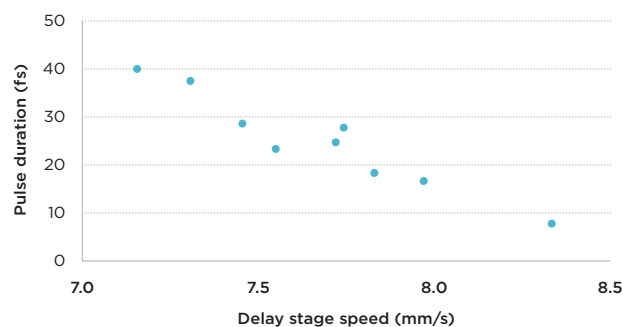


speed of the delay stage, which translates into a temporal jitter that blurs measurement and optimization of the femtosecond laser pulses. Figure 3 shows the results of this uncorrected variability, which is a minimum measured pulse duration equivalent to 65 fs Full-Width at Half-Maximum (FWHM). Contrary to this result, measurement of the laser spectral profile showed that a minimum pulse-width of one-third this (~20 fs FWHM) should be obtainable from this laser with proper adjustment of the prism compressors.

Inspiration for this solution came from the recent work by Cavalleri et al. [3], who showed it was possible to independently measure the shot-by-shot jitter in a repetitive measurement and post-process the data to reconstruct experiments with a temporal resolution far below the variability of the time resolution (“clocking”). In their case, jitter resulted not from a rapid scanning delay stage but from attempts to synchronize two disparate clocks: one from a large particle accelerator and the other from a laser system. Their method relies on using a residual portion of their laser beam to interrogate the instantaneous electric field of the electron beam produced by the accelerator. In our adaptation, a second laser beam is used to measure the instantaneous position and velocity of the delay stage. Two slits are placed on the delay stage arm so that each time the delay approaches zero (the time when the radiation pressure wave is to be launched), a double pulse of transmitted laser light illuminates a silicon photodiode. A dual-channel digital oscilloscope is used to record each individual sweep of the delay stage and tag it with the stage speed for post-collection data processing.

Figure 4

Measured correlation between stage speed as determined by the double slit optical encoder and the measured pulse duration on each scan.



This method essentially allowed us to create a very short pulse and then measure the response of the material. Future work in this area involves using saturable absorbers, which have already proven to change transparency depending on the intensity of light. This would allow for greater expansion of optics into all-optical computers and other devices. We are also able to measure phase change materials, a process that would permit layered storage, essentially improving future data storage technologies.

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Results and Conclusions

Figure 4 shows a dual oscilloscope trace with both the double-slit pattern and the simultaneous measurement of the femtosecond laser pulse-width. Instead of averaging, a correlation can be established between each scan’s stage speed, v_{stage} (which depends on the slit separation d_{slit} and the measured time between the two slits $\Delta t_{peak-to-peak}$):

$$v_{stage} = \frac{d_{slits}}{\Delta t_{peak-to-peak}}$$

and the length of the laser pulse Δt_{laser} :

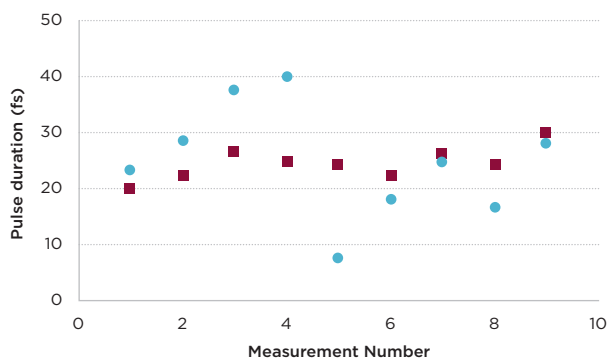
$$\Delta t_{laser} = \frac{v_{stage}}{2\sqrt{2}c} \Delta t_{overlap}$$

where $\Delta t_{overlap}$ is the measured width of the overlap between the first and delayed laser pulse and c is the speed of light in air.

This correlation is plotted in Figure 5. The residual error in pulse-width measurement after this correlation was used to correct the data. The actual pulse-width, in fact, was 40 fs +/- 2 fs, 30% shorter than previously measured. Using this improved measurement, we were subsequently able to reduce pulsed duration to 22 fs by additional adjustment of the internal and external prism compressors. This represents a nearly three-fold improvement in the laser intensity over the non-corrected case and a reduction of timing jitter down to a negligible level. This improved accuracy should make possible the detailed study of the ultrafast response of materials to the transfer of energy and momentum from intense light pulses.

Figure 5

The measured stage speed is used to eliminate the jitter in the original measurement (circles) and results in a low-deviation corrected measurement of the pulse duration (squares).



A.L. Cavalleri et al., Clocking femtosecond x-rays, *Physical Review Letters* 94, 114801 (2005).

Weather Balloons: Constructing an Onboard Data Recorder for Upper Atmospheric Research

Nicole Sprenger*

Abstract The main objective of this project was to construct a weather balloon device designed to collect data from onboard experiments. The device serves as both a reliable and alternate way of obtaining data instead of depending on a radio transmission signal from the weather balloon. The device was constructed by programming a microcontroller to signal data collection from atmospheric sensors, a Geiger counter, and a GPS. The information was then uniformly stored on a USB drive until data analysis took place. The results obtained are consistent with previous flight measurements, implying that the data recorder was working properly. The data recorder will be continued for upper atmospheric research at DePaul University.

Introduction

Weather balloons are commonly used in advanced atmospheric research. On average, weather balloons rise to an altitude of 90,000 ft extending slightly into the second layer of the Earth's atmosphere, the stratosphere. Astronomers and cosmologists seeking to study cosmic rays or to obtain measurements from the electromagnetic spectrum at wavelengths that are absorbed by the Earth's lower atmosphere, known as the troposphere, have turned toward the invention of the weather balloon to achieve such standards (Lutgen and Edward 1982).

Cosmic rays are interesting to study because they contain very high levels of energy. A majority of the rays consist of hydrogen nuclei from the sun, while the remaining consist of helium (alpha rays), energetic electrons, and atomic nuclei (elements known as metals). Non-solar cosmic rays are known to originate in other high-energy events such as supernova remnants. However, the details of the mechanisms by which these cosmic rays are created is still poorly understood. Thus, greater understanding of the origin and composition is a main objective in current astrophysics research.

In order for a cosmic ray to be created, the nucleus of an atom must be stripped of all or some of its electrons, and then excited by solar, galactic (related to the galaxy), or extragalactic (originating beyond the galaxy) energy sources. When cosmic rays penetrate the Earth's atmosphere, they collide with air molecules. Collision causes the air molecules to fragment into a shower of lower energy particles. Some of the particles decay into other particles, such as gamma rays and muons, while the

remaining particles continue toward the Earth's surface. Because the Earth's lower atmosphere helps to shield the incoming rays, at higher elevations a greater amount of cosmic rays exist. Thus, the weather balloon is a convenient method for reaching levels beyond the Earth's lower atmosphere to obtain readings of cosmic rays (Verhage 2006). Although often used for complex research, with a little training, people of all ages can perform weather balloon experiments at various levels.

Weather balloons should be launched in a rural environment, such as a large open field, to enable a smooth ascent and to limit damage to the balloon by collision with external objects and by losing signal connections between the onboard transmitter and the chase vehicle.

Microcontrollers, small devices that can be programmed to control various processes, were used for this project to control the process of data collection. Figure 1 depicts the microcontroller used for the weather balloon launches, and shows how the device can communicate with various experiments.

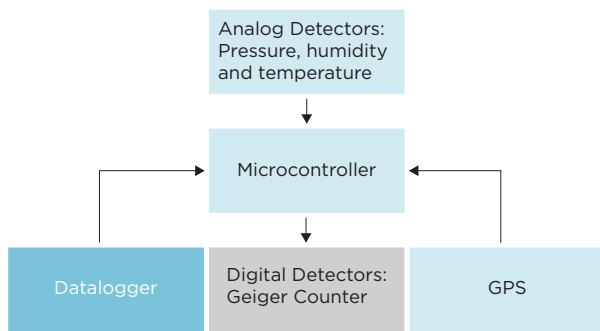
Purpose

During the winter quarter of 2009, DePaul's Society of Physics Students decided to pursue weather ballooning as an ongoing project to gain hands-on experience with science. A unit that transmits scientific and GPS data onboard the flight was purchased from the company Stratostar. This onboard unit is connected via a 900 MHz radio transmitter to a receiver located in the chase vehicle on the ground, and thus acts as the primary source of collecting data from onboard experiments. However, during early flights in spring 2009, it was found that the signal from the onboard transmitter to the receiver on the ground was frequently disrupted, resulting in the loss of valuable data.

* Advisor: Bernhard Beck-Winchatz, Scientific Data Analysis and Visualization Program. Summer 2009. Nmarie219@gmail.com.

Figure 1

The microcontroller in Diagram 1 measures the voltages from the analog detectors and pulses from the digital detectors that are reading latitude, longitude, and altitude. The microcontroller also records the time from the GPS. All this information is then stored on the datalogger. The measurements of pressure, temperature, and humidity are in volts because the atmospheric sensors generate analog signals, which use some property of a medium, in this case voltage, to convey information. When the voltage is measured, the microcontroller is actually obtaining scientific data from the atmospheric sensors. When a Geiger counter detects radiation, a pulse is generated; thus, the digital detector produces pulses. The microcontroller acts as an alternate method of gathering data by obtaining information from various experiments and storing the information on the datalogger device.



A rural environment limits but does not eliminate this problem. As research becomes more complex, individuals may look for alternate methods of collecting data to ensure that no data is lost during flight. Also, the need for sophisticated technology may increase. For example, an experiment may require collecting to be turned on and off throughout the flight, or data may need to be captured over a specific time interval. Microcontrollers permit this through the use of computer programs coded to accommodate multiple experiments and proper storage of data.

The purpose of this project was to construct an onflight data retrieval device designed for a weather balloon in order to both obtain and store in a uniform manner: readings of pressure, humidity, temperature, altitude, and radiation from the Earth's upper atmosphere. This onboard device provides an alternate way of collecting data instead of relying on a radio transmission signal from the weather balloon.

Methods

The systematic technique for this project was to write a computer program transferred to the Microcontrollers via PC connection. Once the program was saved to the device, the microcontroller was placed on a breadboard and connected to experimental sensors, a GPS, and an RM-60 Geiger counter through basic cir-

cuit wiring. The experimental sensors collected temperature, pressure, and humidity data from the upper atmosphere. The atmospheric sensors generate voltages while the Geiger counter generates pulses. The pins of the microcontroller measure these voltage, count the number of pulses, and then record this information on a USB drive.

Microcontrollers act as miniature computers. Although small in size, these tiny chips have the power to control various types of electronic devices. Microcontrollers can be found in day-to-day electronics such as microwave ovens, cell phones, alarm clocks, and automatic doors. In addition, robots, aerospace design, and other high-tech devices use microcontrollers. These small chips sufficiently qualify for use in a weather balloon flight (Lindsay 2003).

The signaling of data collection activated a datalogger device connected to a USB drive, storing information from the sensors, GPS, and RM-60 Geiger counter. The microcontroller was programmed to signal collection over ten-second intervals continuously throughout the flight. After the weather balloon had been retrieved, the USB port was plugged into a computer and the data file was opened through Excel. The results were presented with precise dates along with the length of the flight, and the proper heading for each atmospheric sensor.

Results

The results section is broken up into two parts, Launch 1 and Launch 2; both are preceded by separate analysis sections. Launch 1 contains the data collected from the flight of July 20, 2009 and Launch 2 contains the data obtained from the flight of July 29, 2009. Separate sections are necessary as the graphs of Launch 1 represent external readings of the upper atmosphere whereby the atmospheric sensors were flown outside the pod, while results depicted in the graphs of Launch 2 represent an internal reading of the environment from the atmospheric sensors flown inside the pod.

Readings of both the external and internal environment throughout the flight are needed to understand how the external characteristics of the upper atmosphere fluctuate with increasing altitude and how the environment inside the pod changes. Obtaining information from inside the pod allows investigators to monitor the conditions concerning power supplies and scientific instruments, and to understand how much heat the experiment is generating or how much radiation can penetrate the pod and reach the Geiger counter. Both concepts become interesting when comparing data from the internal and external environments because different results are obtained.

Launch 1, July 20, 2009

The first launch took place at Koerner Aviation field in Kankakee, Illinois. Figures 1.1-1.4 represent the external environment as the weather balloon ascends into the stratosphere. That is, atmospheric sensors collecting data on pressure, temperature, and humidity were flown outside the pod, while the rest of the experiment including the onboard data retrieval device, Geiger counter, and GPS were tightly secured inside the pod. Figure 1.1, illustrates counts measured by the cosmic ray detector in units of counts per second, cps, versus altitude measured in meters, m.

Figure 1.2, is a graphical representation of temperature (Celsius) versus altitude (m). Figure 1.3, represents pressure in units of pounds per square inch (PSI) versus altitude (m). Figure 1.4, is a graph showing relative humidity, RH, plotted against rising altitude. RH compares the amount of water vapor in the air to the maximum possible at the current temperature, and is measured as a percentage.

Launch 2, July 29, 2009

The second launch occurred on an athletic field in Chenoa, Illinois. Figures 1.5-1.9 represent the internal environment of the pod as the weather balloon ascends into the stratosphere. That is, atmospheric sensors collecting data of pressure, temperature, and humidity were flown inside a pod along with an additional experiment. The additional experiment was a scintillation counter constructed by DePaul's Chicago Initiative for Research and Recruitment in Undergraduate Science (CIRRUS), program. The two projects were placed and wired to permit the data recorder to collect information for both experiments. Figure 1.5, represents the data collected from the Geiger counter, counts (cps) vs. altitude (m).

Figure 1.6 represents the temperature in degrees Celsius that was recorded from the atmospheric sensors and plotted against rising altitude. Figure 1.7 depicts pressure readings obtained from the second launch plotted against rising altitude. Figure 1.8, is a graph showing relative humidity plotted against rising altitude.

Analysis Launch 1

In Figure 1.1, cosmic ray detection increases until an altitude of about 25,000 m where it begins to decrease. The initial increase occurs because the upper atmosphere filters out secondary, low energy, cosmic rays. That is, when low energy cosmic rays originating from the sun penetrate the upper atmosphere, nitrogen and oxygen molecules collide. As a result, low energy particles are absorbed in the upper atmosphere and the detection of cosmic rays increases (Verhage 2006).

At altitudes where radiation levels start to decrease, cosmic rays of higher energy, known as primary cosmic rays, exist along with unfiltered secondary rays. However, radiation detection decreases because less energy is absorbed by the atmosphere.

Figure 1.2, depicts the air temperature decreasing with rising altitude until the stratosphere is reached. Around 10,000 m, atmospheric sensors detect a rise in temperature. This can be attributed to the point where the weather balloon passes through the tropopause and begins its ascent into the stratosphere. Frigid temperatures are detected at lower altitudes in the troposphere where the temperature of an air parcel generally decreases with height at a specific ratio known as the lapse rate. That is, when a heated air parcel rises, it expands because pressure decreases at higher altitudes. Expansion causes the air parcel to exert a force on the surrounding air; however, no heat is gained. This adiabatic process is responsible for decreasing temperatures with rising altitudes (Burt and Aguado 2000).

Before the balloon reaches the stratosphere, it must pass through the tropopause where air ceases to cool with height and temperatures are constant. As the balloon continues to rise, the constant temperature profile encounters increasing temperatures in the stratosphere. There, heating is largely the result of solar radiation absorbed by ozone. Figure 1.2, shows that at an altitude of 15,000 m the balloon pops, and temperatures are higher.

Atmospheric pressure can be thought of as the weight of the atmosphere exerted over the surface of the Earth. In Figure 1.3, atmospheric pressure decreases with height because fewer air molecules are present at higher altitudes. Since the atmosphere is a gas, and gases are compressible, and fewer air molecules exist at higher elevations (Burt and Aguado 2000). In Figure 1.3 data from altitudes below 3,000 m is missing from the graph due to a temporary malfunction of the instrument.

Figure 1.4 demonstrates that relative humidity decreases with rising altitude. A decrease in relative humidity occurs because there is more water vapor in warmer than colder air. Thus, at colder temperatures such as those found in the troposphere, relative humidity decreases. Because relative humidity depends on both the actual moisture content and the air temperature, humidity changes as the surrounding air temperature fluctuates. From Figure 1.2, it is evident that temperature decreases with rising altitude until regions close to the stratosphere are reached; however, relative humidity drops around an altitude of 10,000 m, maintaining these low values as the balloon continues to rise. Notice in Figure 1.3, that readings above 100% are detected. Readings above 100% are caused by the noise of the detector and are responsible for the 'jagged' appearance of the graph. Thus, readings close to the value of 100% are in fact pushed to higher values.

Figure 1.1

In Figure 1.1, counts, represented on the x-axis, increase with rising altitude until a height of approximately 25,000 meters, when the amount of cosmic rays detected decreases until the balloon bursts and descends from the upper atmosphere.

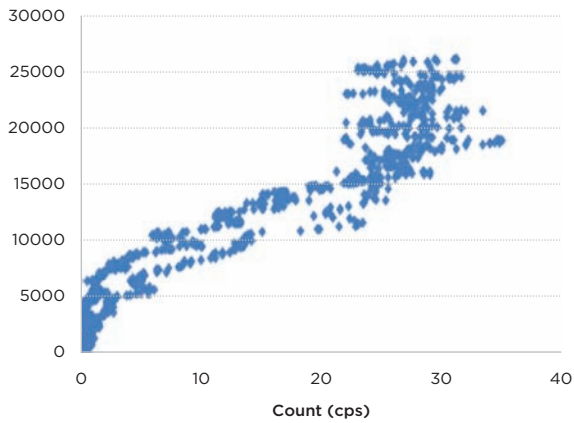


Figure 1.2

Figure 1.2 illustrates a rapid temperature decrease starting from about 30° Celsius and declining to about -54° Celsius as higher altitudes are reached. Notice that at a certain point the temperature begins to rise as the balloon continues to ascend into the stratosphere. When the balloon pops at an altitude of about 26,000 m, the temperature begins to decline once more but does not reach temperatures below -50° Celsius.

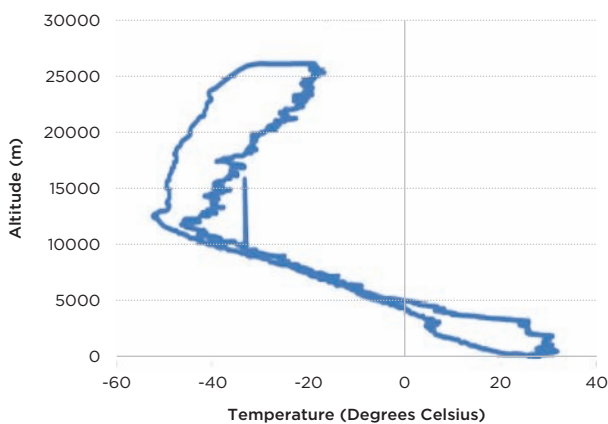


Figure 1.3

Figure 1.3, shows that the pressure of the external environment decreases exponentially with rising altitude. This decrease causes the balloon to expand as it ascends. Air pressure readings from the ascent and descent of the balloon's flight follow a similar line. Since it is unlikely that air pressure in the stratosphere or troposphere would have changed over the short period of a weather balloon flight, you'd expect to see similar patterns before and after the balloon pops.

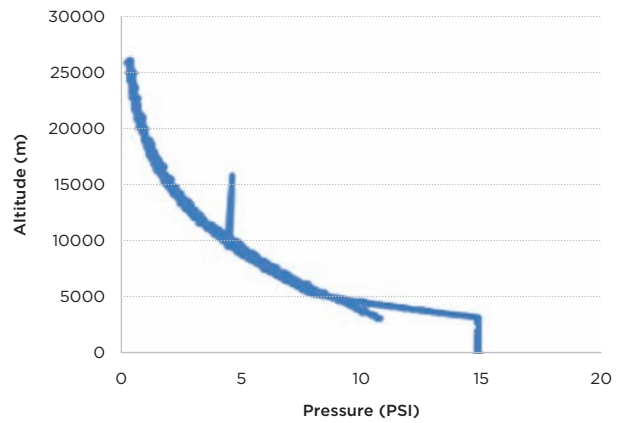


Figure 1.4

Figure 1.4, shows that relative humidity decreases with rising altitude. At lower altitudes such as 500 m, humidity levels measure close to 40%. At higher altitudes, humidity readings are less than 6%. After the balloon pops, humidity levels increase as the balloon falls back to Earth. The graph of relative humidity is actually a line, not just one point. This is because the amount of water vapor present in the air decreases with rising altitude in correlation with decreasing temperatures. Thus, the readings of relative humidity vary with rising altitude.

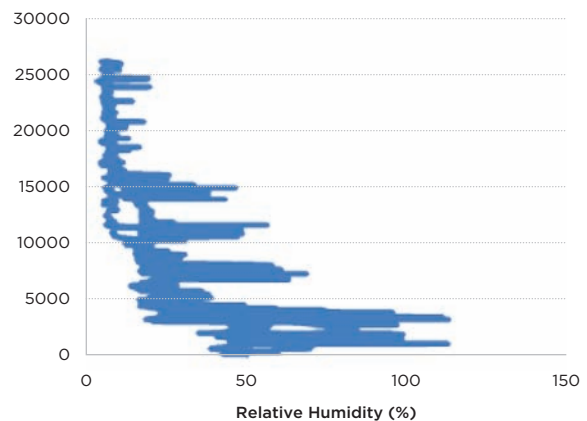
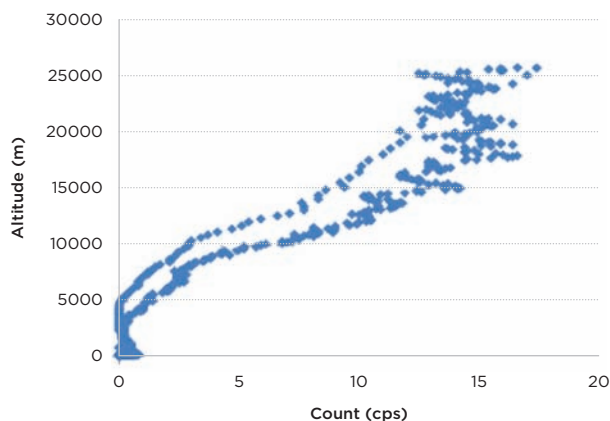


Figure 1.5

From Figure 1.5, it is apparent that counts, represented on the x-axis, increase with rising altitudes up to a height of about 25,000 m. After the balloon pops, a decrease in the amount of cosmic ray detection is apparent. Figure 1.1 and 1.5 exhibit a similar shape, however, the amount of cosmic rays detected on launch 1 is greater than that detected on launch 2. Launch 1 detected a maximum of about 55 cps, while launch 2 detected a maximum of about 30 cps.



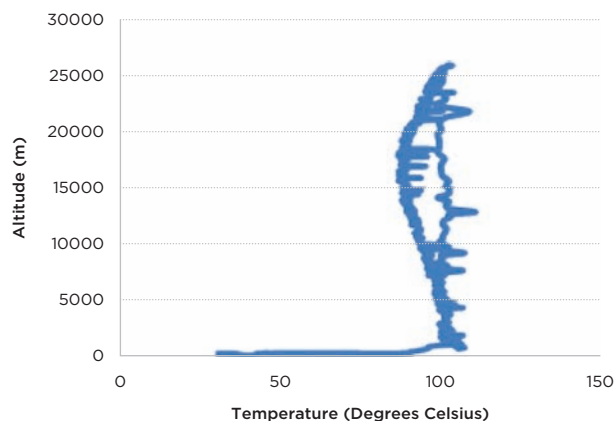
Analysis Launch 2

Similar to the results found in Figure 1.1, Figure 1.5, shows that cosmic ray detection increases until an altitude where it begins to decrease. During both flights, the Geiger counter was orientated horizontally with the mica window facing sideways and remained inside the pod. However, the mica window, was exposed during the first launch, but not during the second, allowing alpha particle penetration to take place. During the second launch, the Geiger counter was also underneath the CIRRUS experiment. One reason why cosmic ray detection decreased during launch 2 could be that only particles with enough energy to penetrate through the CIRRUS experiment were detectable by the Geiger counter.

Figure 1.6, depicts increasing temperature with rising altitude, contrary to the results in Figure 1.2. Temperatures climbed to the extremities of one 100° Celsius. High temperature readings for the July 29 launch were recorded because this project was placed with an additional project constructed by CIRRUS. The CIRRUS experiment was wired to the breadboard and the microcontroller programmed to signal data collection and storage for the additional project. Thus, the readings of the internal temperature from inside the pod suggest that both experiments generated great heat. The pod carrying both experiments also acted as an insulator, maintaining warm temperatures inside the pod while outside the pod, the frigid temperatures continued to decline into negative digits.

Figure 1.6

Contrary to Figure 1.2, Figure 1.6, depicts an increase in temperature with rising altitude. Note that Figure 1.6 is a representation of the internal temperature inside the pod. As the graph shows, even at as low an altitude as 5,000 m, the temperature begins to increase as the balloon rises and remains very hot as readings linger at about 100° Celsius. Even after the balloon pops, temperatures do not decrease but instead remain close to 100° Celsius.

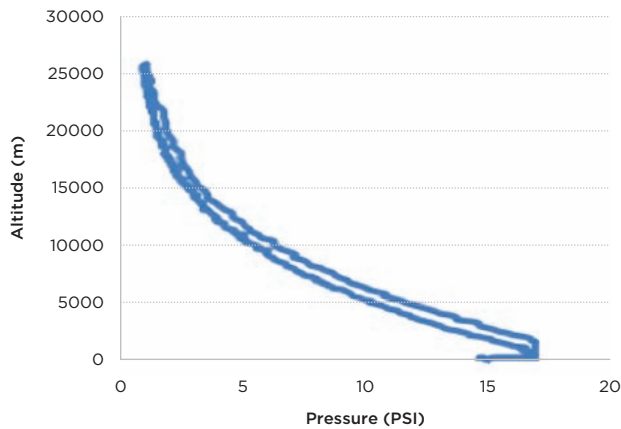


In Figure 1.7, the pressure of the internal environment decreases exponentially with increasing altitude, similar to the results obtained in Figure 1.4 depicting pressure readings of the external environment. However, slight differences occurred during the ascent and descent of launch 2. The external pressure of the upper atmosphere does not fluctuate greatly from the time when the weather balloon is launched until it pops; therefore, the pressure readings between ascent and descent remained relatively similar. However, the pressure readings obtained from inside the pod were slightly different than those found in Figure 1.4; the temperature readings depicted in Figure 1.6 for Launch 2 were considerably higher than the values obtained during Launch 1. Thus, during launch 2, both temperatures inside the pod and pressure readings increased. In Figure 1.7, slight differences in the pressure readings during ascent and descent are detected, likely due to the higher temperature profile maintained inside the pod during descent.

As seen in Figure 1.8, humidity begins to increase with rising altitude inside the pod, contrary to the humidity levels found in Figure 1.4, showing recorded values outside the pod. Humidity levels rise because temperature increases. When air is warm, it can hold more water molecules. Thus, in Figure 1.6, humidity levels spike as the temperature inside the pod begins to rise. After the balloon pops, humidity levels remain relatively high until an altitude of about 5,000 m where values start to decrease despite

Figure 1.7

Figure 1.7 indicates a slight variation in pressure readings between ascent and descent. The pressure of the internal environment decreases exponentially. Although pressure readings increase slightly right after launch to about 16 PSI, after altitudes of about 1,000 m, pressure begins to decrease until the balloon pops. After that, pressure increases as the balloon continues its descent.



the temperature readings, remaining close to 100° Celsius. Because the temperature inside the pod remains high, less moisture is detected. As the balloon continues falling, an unusual spike of about 30% occurs in the RH values between approximately 2,000 m and 600 m. This spike is unusual because temperature profiles as found in Figure 1.6 do not decrease during these altitudes. Additional testing is needed to further explain this increase.

Conclusion

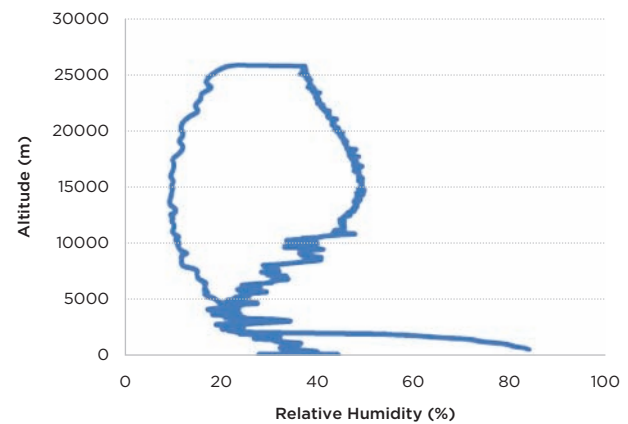
These results are consistent with previous flight measurements, implying that the data recorder was working properly. Figures 1.1-1.5 depict external atmospheric recordings and show differences from figures 1.6-1.8, which provide readings of the internal

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Figure 1.8

In Figure 1.8, humidity increases with the rising altitude inside the pod. During ascent, at lower altitudes such as at 500 m, humidity levels measure close to 40%. At higher altitudes such as 20,000 m, humidity measures about 43%. As the balloon nears its maximum height, humidity levels begin to decrease. During descent, at higher altitudes such as 25,000 m, humidity levels drop nearly 20% and continue to fall. However, at lower altitudes of about 20,000 m the RH spikes nearly 30% as the RH values rise from about 25% to readings close to 83%.



environment of the pod. As discussed, several features depicting the internal readings of the graphs remain unexplained and will need to be further investigated. The data recorder will be used for future flights and will continue to be considered both an alternate and reliable way of obtaining data during a weather balloon flight.

Acknowledgements

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Non-Gaussian and Anisotropic Signatures in the Cosmic Microwave Background

Sarah J. Washburn and Jennifer Smith*

Abstract Most models of the universe naively expect matter to be distributed evenly and assume the universe has no preferred direction, exhibiting isotropy, and that matter should be distributed randomly, defined as a Gaussian distribution. Using novel mathematical techniques, we examine these assumptions based on the 5-year Wilkinson Microwave Anisotropy Probe of the Cosmic Microwave Background. In this work, we checked these assumptions using novel mathematical techniques. Our results indicate that the Cosmic Microwave Background may be neither isotropic nor Gaussian.

Introduction

Cosmic Microwave Background

The Cosmic Microwave Background (CMB) is the leftover radiation from the original formation of neutral hydrogen. Discovered in 1964 by Arno Penzias and Robert Wilson, the CMB formed approximately 380,000 years after the birth of the universe, 13.7 billion years ago. The CMB originated as high energy, short wavelength radiation and is now in the microwave range as a result of the expansion and cooling of the universe. Because the CMB is the oldest light in the universe, it provides crucial data to test various aspects of the formation of stars and galaxies as well as probe the conditions of the early universe.

The CMB is distributed almost completely uniformly. However, there are small fluctuations (appearing as minute temperature differences) that provide crucial information about the geometry, material composition, and thermodynamic status of the early universe. For example, the size distribution of the fluctuations can tell us if the universe is flat, positively, or negatively curved. It is also a basic prediction of the Big Bang Model for the evolution of the universe and its existence serves as an essential element for the acceptance of this model.

Because the fluctuations are thought to arise from well-known quantum effects, there is a theoretical basis for believing that their size distribution is random, or Gaussian, and that temperature distribution is spatially uniform or, isotropic. Recent work has called these assumptions into question, however [1]. Our project further tests these assumptions via a unique probe and additional mathematical analysis.

Wilkinson Microwave Anisotropy Probe

Our main focus is to test the isotropy and Gaussianity of the CMB. That is, we try to determine whether the universe has a preferred direction and whether matter is distributed randomly. This requires a sensitive probe of the CMB. The Wilkinson Microwave Anisotropy Probe (WMAP) is the most precise project to date, designed to determine geometry, content, and evolution of the universe. Launched by NASA in 2001, this satellite observatory is a publicly available survey of the CMB. Data collected from the WMAP consist of measured temperature differences between two points in the universe. That is, by probing the CMB at a 13 arcminute resolution, the WMAP produces accuracy to within one millionth of a degree. This ongoing nine-year project has produced five years of released data and is sensitive enough to test for isotropy and Gaussianity.

Squaring the Sphere

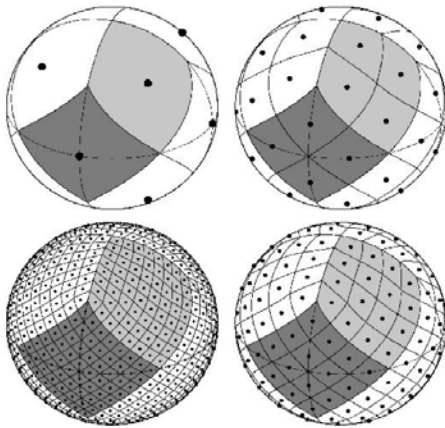
For the purpose of analysis, it is first necessary to manipulate the data such that we can extract necessary information from WMAP. This can be accomplished by using Hierarchical Equal Area Isolatititude Pixelization (HEALPix). Developed in 1997 by K.M. Gorski, HEALPix essentially “squares the sphere.” That is, equal subdivisions of the spherical surface are partitioned into curvilinear quadrilaterals. This makes the data extremely simple for computers to handle—a crucial issue given the extremely large size of the data. Resolution increases with the number of partitions used. The lowest resolution partition is comprised of 12 base pixels. From there, the resolution of the tessellations increases by dividing each pixel into four equal points. The final data contain 12 tessellations each with 512 x 512 pixels. HEALPix produces multi-frequency data sets and constructs full-sky maps that can be efficiently analyzed. The procedure is shown

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graphically in Figure 1; the resolution doubles with each application of HEALPix.

Figure 1

Representation of HEALPix procedure and the production of 12, 48, 192, and 768 pixels evenly distributed on lines of constant latitude.



Wavelet Analysis

We hypothesize that anisotropic and non-Gaussian patterns occur at multiple local scales, as opposed to a single global scale. Consequently, it is necessary to use a mathematical tool that analyzes a distribution locally in scale and position. The discrete wavelet has the exact mathematical properties necessary to test our hypothesis, as it essentially averages locally the data to remove its noisy components and display local attributes that would not normally be visible. The wavelet decomposes a signal into local approximations and local fluctuations at different scales. Each scale represents the original signal in terms of its local density and local fluctuation at that scale. The data are therefore localized and fluctuations become statistically more apparent. For our analysis we employed Daubechies Wavelet developed by Ingrid Daubechies in 1988.

Procedure

Data Collection and Formatting

We obtained the WMAP five-year data from Legacy Archive for Microwave Background Data Analysis (LAMBDA). The data collected by WMAP are a composition of all sources of light that strike the detectors. Because our interests lie solely within wavelengths associated with the CMB, we needed to filter out any extraneous forms of light. Since local and cosmological light is at different wavelengths, the filtering can be accomplished by forming a linear combination of the four different wavelength bands

WMAP detected. After applying HEALPix to the linearly combined data, the resulting data consisted of twelve tessellations, each representing a section of the universe. As mentioned earlier, each tessellation is a grid containing 512 x 512 pixels.

Using the wavelet transform, the grids were split into columns containing approximations and differences. The wavelet transform produces new representations of the original signal with resolutions half the previous resolution. Each scale now is suitable for statistical analysis and a scale-by-scale probe of the CMB is possible.

Analysis

Our analysis involved looking at each row and column of the wavelet transformed data to test for Gaussianity and isotropy. To check for isotropy, we used the approximations produced by the wavelet of each row and column individually. We calculated the mean and variance within each tessellation’s adjacent rows and columns to look for large areas of inhomogeneity. These would strongly suggest anisotropic distributions in the temperature fluctuations, especially when compared across tessellations. Figure 2 shows the third pass of the wavelet transform on the columns of tessellation two, a tessellation in the northern hemisphere of the universe. Figure 3 shows same data set at a higher resolution, producing a more pronounced definition of the nature of the temperature fluctuations. Figures 4 and 5 are the same as Figures 2 and 3, respectively, for tessellation 11 which resides in the southern hemisphere. From Figure 2, we can see that large temperature fluctuations are apparent in the upper right corner,

Figure 2

Tessellation 2 at the third wavelet level, depicting clusters of temperature differences in the upper right corner, suggesting anisotropy.

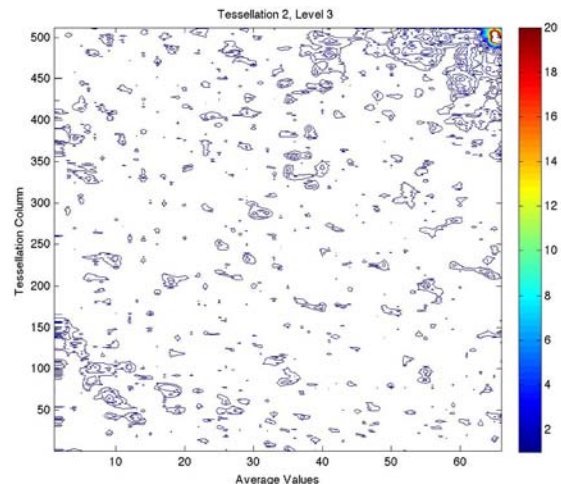


Figure 3

Tessellation 2 at the sixth wavelet level, depicting clusters of temperature differences in the upper right corner, suggesting anisotropy.

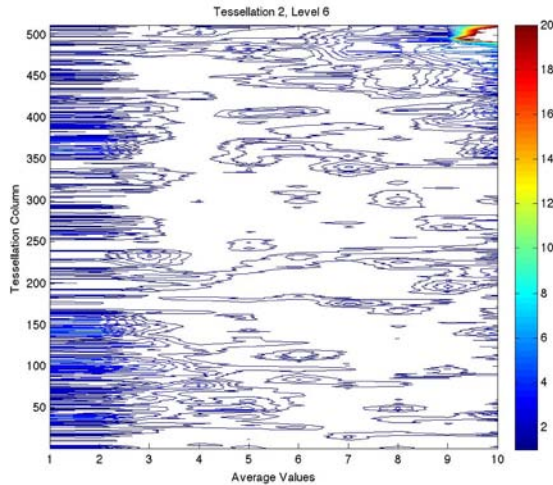


Figure 5

Tessellation 11 at the sixth wavelet level, depicting clusters of temperature differences in the lower left corner, suggesting anisotropy.

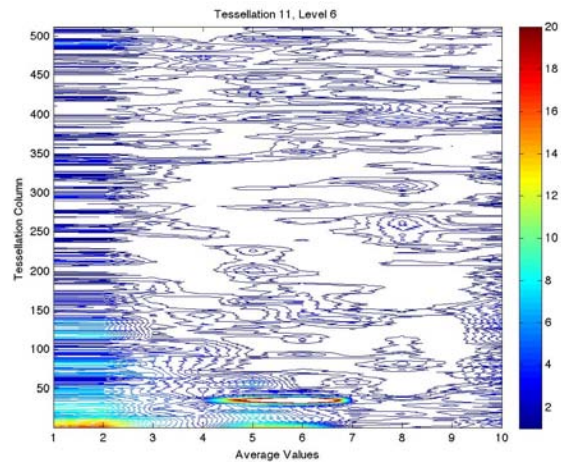
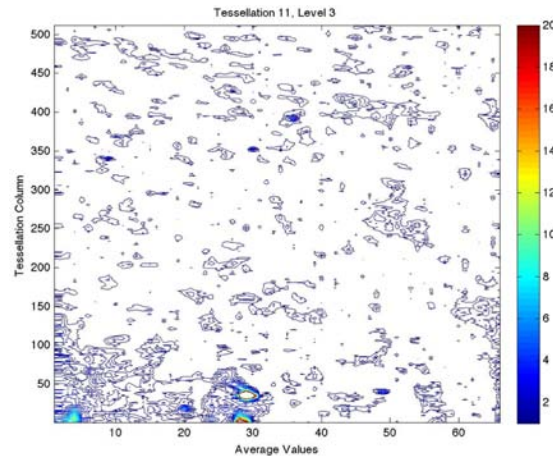


Figure 4

Tessellation 11 at the third wavelet level, depicting clusters of temperature differences in the lower left corner, suggesting anisotropy.



corresponding to the northern pole of the universe. temperature fluctuations are not distributed uniformly throughout the tessellation, this suggests anisotropy. In Figure 3, we see the same tendency at a higher resolution, suggesting that this anisotropic pattern occurs on all local scales. With Figures 4 and 5, the same pattern of clustered temperature fluctuations exists in the lower left corner, corresponding to the southern pole. Again, because these fluctuations seem largest at the pole and dissipate closer to the center, anisotropy is apparent. In addition this distribution also exists at all local scales. Although our figures focus on two

specific tessellations, this pattern occurred in all tessellations. Tessellations 1, 3, and 4 reside in the northern hemisphere sequentially around tessellation 2 and follow the same pole-seeking temperature fluctuation distribution. Likewise, tessellations 9, 10, and 12 are a part of the southern hemisphere and surround

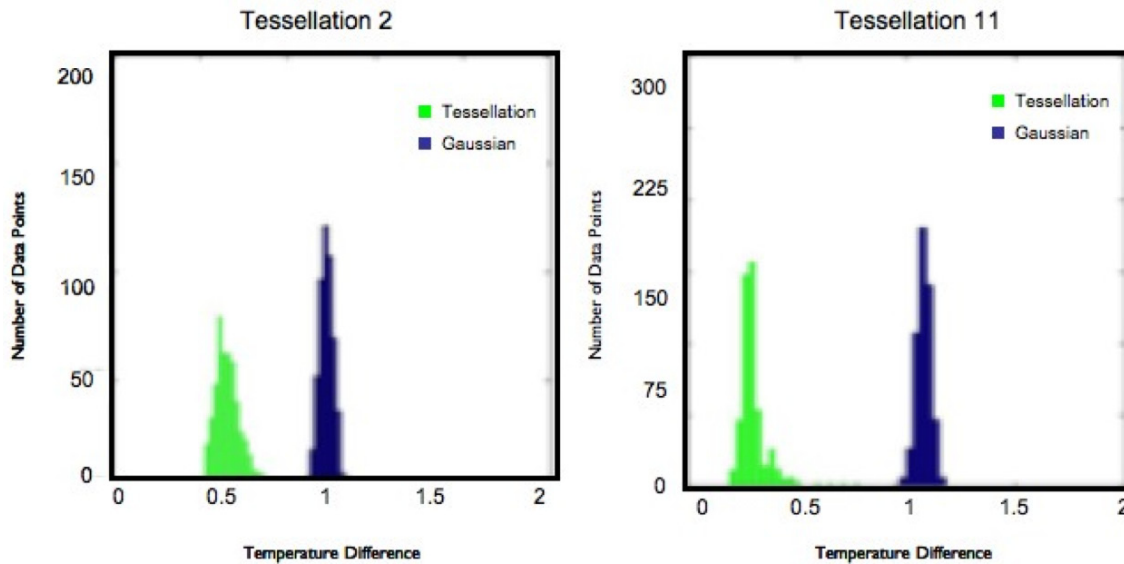
tessellation 11. This consistent pattern suggests an anisotropic nature throughout the universe.

We used a similar procedure to test for Gaussianity. Because non-Gaussian features are best detected via fluctuations from the mean, the differences produced by the wavelet were used. The means of the wavelet transformed rows and columns were compared to those of a randomly generated Gaussian data set to locate differences. A chi-square test was conducted to determine how many rows and columns were Gaussian. On average for normally distributed sets of data, there were approximately 50 differences between rows and columns at all local scales. For all tessellations of the wavelet transformed data, there were approximately 120 differences between rows and columns at all local scales. This suggests a non-Gaussian tendency throughout the universe. Figure 6 depicts tessellations two and eleven, as well as a randomly generated Gaussian data set.

It shows no strong correlation between the Gaussian and real transformed data sets. That is, in both cases the Gaussian distribution is centered around its mean and has the bell-shaped curve associated with normally distributed functions. Although the real data in both tessellations 2 and 11 are centered around a

Figure 6

Depicts a set of normally distributed data (blue) and data from tessellations 2 and 11 (green) at scale 3. Deviations from the mean of both tessellations suggests non-Gaussianity.



value less than the mean and are somewhat bell-shaped, they contain long tails that diverge from the bell-shaped standard. This supports a non-Gaussian nature for temperature differences in both tessellations 2 and 11. While Figure 6 depicts individual tessellations from opposite hemispheres of the universe, this non-Gaussian tendency exists within all tessellations, suggesting that non-Gaussianity occurs throughout the universe.

Conclusion

A distribution that is isotropic should have a density distribution that is statistically homogeneous. Using the wavelet to localize densities in the WMAP CMB data, we see evidence for anisotropy. Figures 2–5 for example, show large temperature differences clustered in the upper right corner of tessellation 2 and lower left corner of tessellation 11. This suggests a nonuniform distribution throughout the universe. The largest temperature fluctuations exist at the poles of the universe, radiating from the center.

Using the wavelet captured fluctuations, we were able to show significant deviations from the Gaussian case, as shown in Figure 6. The deviations occur mostly in two of the tessellations (2 and 11) and were most pronounced at the third level of approximation produced by the wavelet. The non-Gaussian

character of the CMB appears to be a localized feature instead of a global feature.

Cosmology must rely on assumptions that are unrestrictive because all physical laws are involved. The most natural assumption would be that the universe has no preferred direction and is uniformly random. The emergence of more advanced technology is now allowing for tests of these basic assumptions. Our work combines with that of others to suggest that these assumptions may need to be modified. Once confirmed, these findings are likely to raise profound questions about the underlying dynamics that would lead to a universe that is neither isotropic or Gaussian random.

Clearly, much work is needed to confirm these results. First and foremost, the reliability of the maps must be examined. The maps are combined using algorithms that we feel currently best capture galactic foreground contributions but more work needs to be done to clean the cosmic signal from any foreground signals. In addition, because the WMAP data are being pushed to the edge of their reliability, they may not be suitable to test these assumptions. We may have to wait for the recently launched European mission, Planck, to get data with sufficient resolution to test these basic assumptions.

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Marine Vertebrates from the Upper Cretaceous Hartland Shale in Southeastern Colorado

Matt Nagrodski*

Abstract The Hartland Shale Member of the Greenhorn Formation is a sedimentary rock unit that was deposited under the middle of an epicontinental sea in North America, the Western Interior Seaway, approximately 94.3 million years ago (Late Cretaceous: middle Late Cenomanian). Fossiliferous rock samples were collected from the Hartland Shale in southeastern Colorado to analyze the taxonomic composition of its vertebrate fauna. Vertebrate remains were extracted through acid treatment of rock samples. Twenty-six marine vertebrate taxa are identified, including eight chondrichthyans (sharks and rays), 17 osteichthyans (bony fishes), and one marine reptile (marine lizard). Because the identified marine vertebrates are mostly carnivores, the trophic structure of the paleo-community must have been complex.

Introduction

Understanding the characteristics of past environments, including types of living organisms, is important in determining how the Earth has evolved. The Hartland Shale Member of the Greenhorn Formation is an Upper Cretaceous sedimentary rock unit that was deposited in the middle of an epicontinental sea in North America, the Western Interior Seaway. Although the presence of fish remains has been noted in the Hartland Shale (Hattin, 1975), virtually nothing is known about the vertebrate fauna of the stratigraphic member. In January 2006, a USDA Forest Service paleontologist discovered a Hartland Shale exposure (“Bear Springs locality”) containing a thin fossiliferous calcarenite bed in the Comanche National Grassland in southeastern Colorado. In April 2008, several calcarenite samples from the horizon were subsequently sent to DePaul University in Chicago, for an examination of the composition of vertebrate remains. The purpose of this study is to report the taxonomic composition of the vertebrate fauna in the Hartland Shale that offers new insight into the paleoecology of the Western Interior Seaway during its deposition.

Materials and Methods

The rock samples that sparsely show fish remains were collected directly from the rock exposure. Except one rock slab, all samples, that weighed approximately 2.3 kg (5 lbs) in total, were submerged under household vinegar (i.e., 5% acetic acid solution) to dissolve the calcium carbonate. On average, 3.8 l (1 gal) of vinegar was replaced every one to two weeks for approximately nine

months. Except for two rock slabs that were only partially dissolved, the remaining rocks were completely dissolved to extract undissolvable components. Disaggregated residues were collected and rinsed with tap water to remove calcium acetate left over from the vinegar dissolving the calcium carbonate. The fossils in the washed disaggregated materials were then picked using a dissecting microscope. Many hours were spent extracting the fossils under the microscope, although some larger (>5 mm) fossils were occasionally found and could be picked using the naked eye. All specimens are on deposit in the vertebrate paleontology collection of Fort Hays State University’s Sternberg Museum of Natural History in Hays, Kansas (catalogue numbers: FHSM VP-17479 – VP-17542, VP-17553 – VP-17555).

Results

The dissolved rocks yielded numerous isolated teeth and bones of marine vertebrates, although a few fish jaws with teeth also were found. While precise identification of an estimated 10,000 collected items remains uncertain, almost 5,250 pieces have been taxonomically identified and consist of 26 taxa comprising eight chondrichthyans (sharks and rays), 17 osteichthyans (bony fishes), and one reptile (marine lizard) (Table 1; Figure 1). Teeth of the bony fish species, *Enchodus gladiolus*, followed by *Pachyrhizodus minimus*, are found to be the most common identifiable vertebrate fossils found in the rock.

Discussion

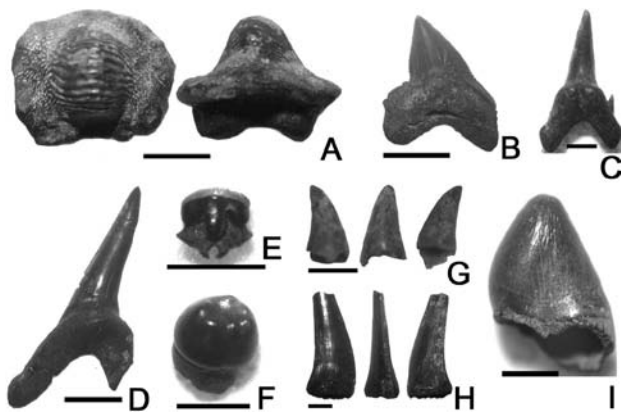
The examined rocks are calcareous and contain shell remains of invertebrates (bivalves) such as *Inoceramids* and *Exogyra aff. E. boverensis*. The acetic acid that dissolved the rock slabs also

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Table 1

Taxon	Sample size	KS	CO
Chondrichthyes:			
<i>Ptychodus anonymus</i>	35 teeth	X	X
<i>Squalicorax curvatus</i>	3 teeth	X	X
<i>Squalicorax falcatus</i>	17 teeth	X	X
<i>Carcharias saskatchewanensis</i>	24 teeth	X	X
<i>Aecheolamna kopingensis</i>	4 teeth	X	X
<i>Cretoxyrhina mantelli</i>	4 teeth	X	X
<i>Creтомanta canadensis</i>	1 tooth	X	X
<i>Rhinobatos</i> sp.	4 teeth	X	X
Chondrichthyes indet.	1 vertebra	NA	NA
Osteichthyes:			
<i>Micropycnodon kansasensis</i>	3 teeth	X	X
<i>Palaeobalistum</i> sp.	5 teeth	-	X
<i>Protosphyraena</i> sp.	6 teeth	X	X
<i>Plethodidae</i> indet.	7 teeth, 6 bones	X	X
<i>Elopopsis</i> sp.	22 teeth	-	-
<i>Pachyrhizodus minimus</i>	1,504 teeth	X	X
<i>Pachyrhizodus</i> sp.	1 tooth	X	X
Albulidae indet.	1 tooth plate, 4 pieces	X	X
Caturidae indet.	2 teeth	X	-
<i>Cimolichthys nepaholica</i>	8 teeth	-	-
<i>Enchodus gladiolus</i>	3,489 teeth, 1 jaw bone	X	X
<i>Enchodus shumardi</i>	12 teeth	X	X
<i>Apateodus</i> sp.	3 teeth	-	-
Teleostei indet. (sp. A)	8 teeth	X	X
Teleostei indet. (sp. B)	17 teeth	X	X
Teleostei indet. (sp. C)	11 teeth	X	X
Teleostei indet. (sp. D)	2 teeth	-	-
Teleostei indet.	1 jaw bone	NA	NA
Osteichthyes indet.	18 vertebrae	NA	NA
Reptilia:			
<i>Coniasaurus crassidens</i>	18 teeth	X	X
Miscellaneous:			
Vertebrata indet.	ca. 10,000 bone fragments	NA	NA
Vertebrata(?) indet.	35 pebbles	NA	NA

Figure 1



dissolved the calcareous shells. *Exogyra* aff. *E. boverensis* is biostratigraphically important because its occurrence is constrained to the middle Late Cenomanian (see Hattin, 1975). This record places the deposition at the Hartland Shale to approximately 94.3 million years ago (Ma) (Kauffman et al., 1993).

The deposition of the Hartland Shale marks the transgressive phase (advancing seawater) of the Greenhorn Cyclothem when the Western Interior Seaway was expanding (Hattin, 1975). However, the examined calcarenite slabs were observed to have many clayey fragments, and vertebrate remains were mostly isolated and fragmentary. These observations characterize the calcarenite bed as a lag deposit where the clayey materials likely represent storm-generated rip-up sediments formed during a brief period of regression (receding seawater) as the sea level temporarily dropped in the area.

This study represents the first analysis of the vertebrate fauna in the Hartland Shale, and Table 1 lists all the identified taxa. Table 1 also shows taxa found in the base of the Lincoln Limestone that stratigraphically underlies the Hartland Shale in central Kansas and southeastern Colorado based on published data. The basal Lincoln Limestone in central Kansas is chronologically similar to the Hartland Shale at the Bear Springs locality (94.3 Ma; middle Late Cenomanian) dated to the early Late Cenomanian (ca. 94.6 Ma; Shimada and Martin, 2008). On the other hand, the basal Lincoln Limestone in southeastern Colorado is slightly older, middle to late Middle Cenomanian in age (ca. 95 Ma; Shimada et al., 2006). One striking observation is that the taxonomic composition of the two Lincoln Limestone faunas is very similar to the Hartland Shale fauna examined here. In fact, the only species from the Hartland Shale that were not identified in both Lincoln Limestone localities are *Elopopsis* sp., *Cimolichthys nepaholica*, *Apateodus* sp., and “Teleostei indet. (Species D)” (Table 1).

All identified bony fish taxa are small- to medium-sized carnivores, consisting of presumed piscivores (fish eaters: *Carcharias*, *Protosphyraena*, *Cimolichthys*, *Elopopsis*, *Pachyrhizodus*, *Enchodus*, and the four unidentified teleosts; e.g., Figure 1C, G, H) and durophagous forms (shelled animal eaters: *Ptychodus*, *Rhinobatos*, *Micropycnodon*, *Palaeobalistum*, *Plethodidae*, and *Albulidae* that possibly fed on crustaceans; e.g., Figure 1A, E, F) (e.g., see Shimada et al., 2006, and references therein). *Ptychodus* (Fig. 1A) is a durophagous shark that presumably fed on shelled mollusks, whereas *Squalicorax*, *Archaeolamna*, and *Cretoxyrhina* (e.g., Figure 1B, D) are sharks characterized as “large” carnivores (estimated total body length of greater than 1.5 m; see Shimada et al., 2006). *Coniasaurus crassidens* (Figure 1I) is a small durophagous aquatic lizard (< 1 m in length; see Shimada et al., 2006)

and represents the only tetrapod from the locality to date. The fact that the identified marine vertebrates are dominated by carnivores, including forms that fed on fishes and shelled animals, suggest that the trophic structure of the paleocommunity was likely complex.

The present study reveals a small piece of Earth's history, recognizing many unanswered or unaddressed questions. What are the reasons for the Western Interior Seaway's transgressive phases with brief periods of regression? What kind of effects did the transgressive and regressive phases have on the fauna in the area? Further research on such paleoenvironmental questions would provide additional insights into the evolution of Earth systems.

Acknowledgements

I thank Dr. Bruce A. Schumacher (USDA Forest Service) for supplying Dr. Kenshu Shimada and me with the rock samples and stratigraphic data reported here. I also thank the Environmental Science Program at DePaul University for financial support.

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Stephanie Valencia
I Need to Get Out More
Adobe Photoshop CS2

The Relationship between Isoprene Stimulation and Photosynthesis Reduction during Drought Stress in Cottonwoods (*Populus deltoides*)

Caitlin Schulze*

Abstract Plants are known to emit isoprene, a biogenic volatile organic compound (BVOC). The combination of BVOCs with nitrogen oxides from human sources leads to the production of ozone, a harmful air pollutant that damages the respiratory system and vegetation. Ambient carbon dioxide levels were varied for cottonwood and northern red oak plants under drought-stress conditions to investigate the biochemical controls on isoprene emissions under global change conditions. Temperature was also varied to demonstrate that the substrate dimethylallyl diphosphate (DMAPP) is limiting at lower but not higher temperatures. These results will aid efforts to model future isoprene emissions.

Introduction

The portion of the atmosphere closest to the Earth's surface, the troposphere, affects human activities because of its direct contact with the Earth. Nitrogen oxides (NO, NO₂), also known as NO_x gases, are air pollutants that form from vehicles, industries, power plants, and other anthropogenic sources (Oxtoby, Freeman, and Block 2003; Ryerson et al., 2001). When nitrogen oxides react with volatile organic compounds from anthropogenic or biogenic sources, they create tropospheric ozone, which is the most plentiful oxidant in the atmosphere. At high concentrations, ozone is harmful to human health and the biotic world.

Biogenic volatile organic compounds (BVOCs) are emitted from plants and react with the NO_x gases to form ozone and peroxy radicals. These radicals lack paired valence electrons and usually result in highly reactive species. The reaction of BVOCs and these radicals lengthens the amount of time some greenhouse gases remain in the atmosphere (Pegoraro et al., 2007). One specific species of BVOCs is isoprene, which has the highest production rate and largest global emissions from plants (Guenther et al., 1995).

This study investigates the relationship between isoprene and carbon dioxide levels in the plant, which is important amidst the threat of global warming. One result of global warming is the increase in drought stress conditions for plants. Carbon dioxide is a greenhouse gas that contributes to global warming. Incorporation of this gas into the project will allow for predicting the effects of future carbon dioxide levels on the plants, while simultaneously studying isoprene emissions. This information can be

used to further the field of atmospheric chemistry, and to explore the full consequences of carbon dioxide-emitting industries.

Drought stress conditions for the plants were explored by simulating drought conditions, which suppress photosynthesis. Under normal circumstances, isoprene emissions increase as photosynthesis increases, but in drought stress conditions, isoprene initially increases while photosynthetic rate declines (Pegoraro et al., 2007). The carbon dioxide levels were varied because of the relationship between them and photosynthesis; an increase in carbon dioxide increases the photosynthetic rate of the plant but suppresses isoprene emission by reducing substrate concentrations.

We hypothesize that isoprene emissions stimulated by drought are caused by an increase in isoprene synthase activity (H1). The hypothesis postulates that the availability of DMAPP does not influence the plant's isoprene emissions, which is instead caused by the increase in isoprene synthase activity. Isoprene synthase is the enzyme that creates isoprene. This would mean that isoprene depends not on the concentration of the substrate DMAPP but instead on the reaction rate of isoprene synthase, which creates the volatile hydrocarbon, isoprene. Second, we hypothesize that the increase in isoprene emissions observed at elevated temperatures is due to an increase in isoprene synthase activity (H2). Under varying temperatures, the photosynthetic rate of the leaf does not vary greatly.

Methodology

This project was conducted in the DePaul University McGowan South greenhouse. Six northern red oak trees (*Quercus rubra*) were used in this experiment from June 20, 2009 to August 27, 2009. The drought conditions began on July 27, 2009. The three con-

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control plants (A1, A2, and A3) were watered three times a week with approximately 0.5 L of water. The three experimental plants (B1, B2, and B3) were also watered three times a week according to the recorded soil moisture percentage. The plant soil moisture below 15% was watered with 0.5 L. The plant soil moisture between 15% and 30% was watered for with 0.25 L and the plant soil moisture above 30% was not watered that day. This procedure was followed until August 21, 2009. After that day, the watering procedure for the control plants was not changed, but the treatment plants were not watered to induce more severe drought conditions. An increase in isoprene and decrease in photosynthesis was not observed in these plants, and is not always seen for red oaks (Pegoraro et al., 2007).

Two new control (A4, A5) and two treatment (B4, B5) northern red oaks were added to the experiment on August 24, 2009 since the previous plants were not experiencing the expected drought stress response. Isoprene and photosynthesis measurements were taken from August 24, 2009 until September 9, 2009. The control plants were watered with 0.75 L and the treatment plants were watered according the recorded soil moisture percentage. Plant soil moisture below 10% received 0.25 L, but above 10% the plants were not watered. This watering procedure began on August 24, 2009.

Three control (C1, C2, and C3) and three treatment (D1, D2, and D3) cottonwood plants (*Populus deltoides*) were used in this experiment from September 18, 2009 until October 18, 2009. The plants were added to the experiment since the increase in isoprene and simultaneous decrease in photosynthesis was not observed in the previous treatments. The watering procedure for the control plants followed that of B1, B2, and B3. The treatment plants were watered according to their soil moisture percentage. The plant soil moisture below 10% received 0.25 L. The plant soil moisture between 10% and 15% received 0.125 L, and above 15% was not watered.

Repeated measurements of each plant were taken two times a week to determine the photosynthetic rate and isoprene emissions. At each measurement, carbon dioxide was varied. Measurements were recorded at carbon dioxide levels of 400 μmol and then increased to 800 μmol , and also with no light. The absence of light provides the background atmospheric isoprene and supplies a zero reading for the detector. Under all conditions, plant isoprene emissions were monitored with a chemilluminance detector.

Hypothesis H2 was explored by varying the leaf temperature at ambient and elevated carbon dioxide concentrations. Plants C1 and C2 did not experience drought conditions during this time, and were watered 0.75 L each day. Photosynthetic rate and

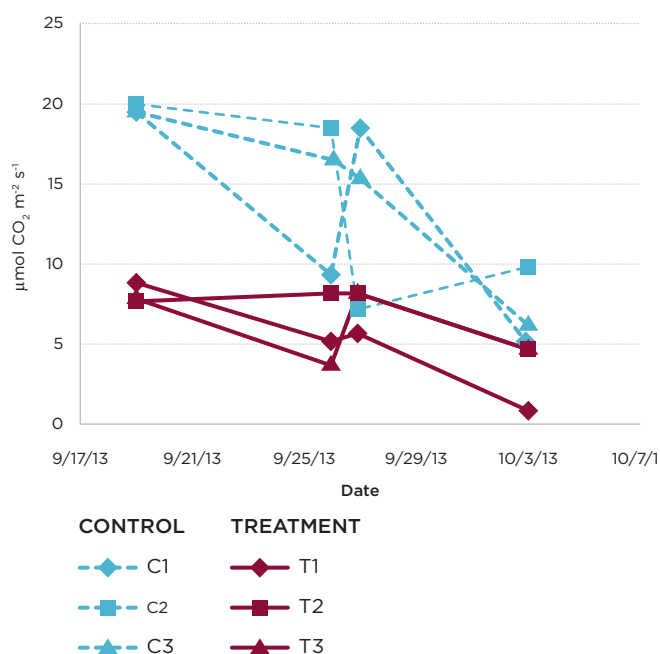
isoprene emissions were measured at 35 °C and then increased to 45 °C at ambient and elevated carbon dioxide levels separately. The carbon dioxide levels were increased from 400 $\mu\text{mol/mol}$ to 800 $\mu\text{mol/mol}$.

Results

The photosynthetic rate for the control (C1, C2, and C3) and treatment (D1, D2, and D3) groups decreased for the second measurement, September 24, 2009 after a drought stress was initiated (Figure 1). The data for red oaks are not included because of the lack of consistency. Although the photosynthetic rate for the control plants did decrease, there was a significant difference between the photosynthetic rate for the control and treatment groups before the treatment began. These data cannot be explained and confound further results. The measured isoprene ratio was significantly different for the control and treatment groups after treatment. The isoprene ratio for the control group showed significant suppression, while the treatment group showed only a slight amount of suppression on September 25, 2009. The results supported H1. The isoprene emission rate for ambient carbon dioxide showed no significant difference between the control and treatment groups (data not shown).

Figure 1

Comparison of photosynthetic rate under non-drought and drought conditions in *P. deltoides*. The data obtained on September 18, 2009 were collected in pre-drought stress conditions, while the data obtained from September 25, 2009 were collected in post-drought stress conditions.



The isoprene ratio for cottonwoods C1 and C2 at varying temperatures is inconclusive (Table 1). Plants C1 and C2 show a significant decrease in suppression on October 14, 2009 when the temperature were increased from 25 °C to 35 °C. The isoprene ratio for plant C1 on October 18, 2009 did not change significantly from 25 °C to 35 °C. The measurements obtained from October 14 supported hypothesis H2, but the measurement on October 18 did not support H2.

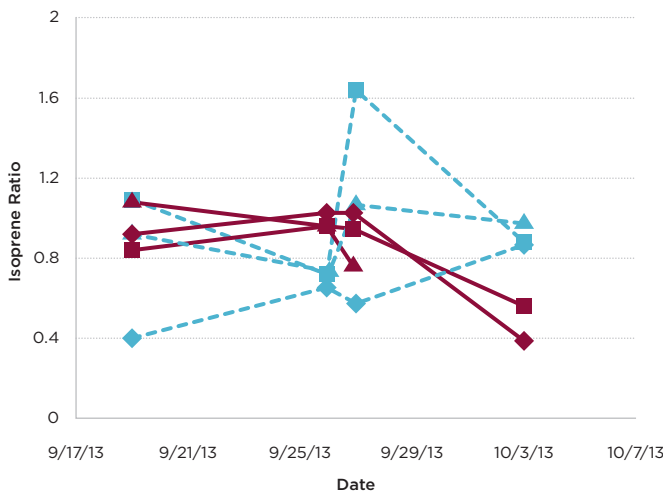
Table 1

The isoprene ratio for *P. deltoides* at 25°C and 35°C. The isoprene ratio was calculated using the 800 Qmol and 400 Qmol values are subtracted by the atmospheric isoprene emission to obtain a corrected value that accounts for the background isoprene concentration

Date	Plant	Isoprene Ratio at 25°C	Isoprene Ratio at 35°C
10/14/2009	C1	0.475942	0.688053
10/14/2009	C2	0.262075	0.69627

Figure 2

The data represented in this graph correspond to the dates and plants in Figure 1.



CONTROL **DROUGHT**

—◆— C1 —◆— D1

—■— C2 —■— D2

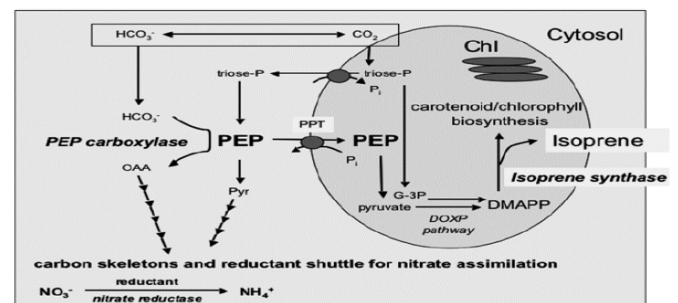
—▲— C3 —▲— D3

Discussion

The photosynthetic rate for the control and treatment plants did not significantly change on the second measurement date after the drought treatment began. We speculate that the plants were not experiencing drought stress conditions. The treatment plants were exhibiting low photosynthetic rates before the treatment began, but the isoprene ratio showed little suppression and there was no significant difference between treatment and control plants for the second measurement. Although H1 was supported, there are two caveats regarding the data: 1) there was a pre-existing difference in the photosynthetic rate of the plants before the treatment began, and 2) the treatment remained constant while the control varied. This could mean that the increase in carbon dioxide decreases the amount of DMAPP utilized by the plant to create isoprene. If the plant is using less DMAPP, which is the precursor to the creation of isoprene, less isoprene is being released. The “safety value” hypothesis produced by Rosentiel et al. (2004) (Figure 3) appears to only apply when the plant is experiencing ambient levels of carbon dioxide. The drought stressed plants do not show isoprene suppression, indicating that these plants emit roughly the same amount of isoprene at ambient and elevated levels of carbon dioxide. The control plants show a little suppression, indicating that less isoprene is being created at elevated levels of carbon dioxide. The plant does not create more isoprene with the intake of carbon dioxide; this suggests that more carbon is used in the PEP synthesis of pyruvate (see Figure 3). Perhaps in drought conditions there could be no regulation on the “safety value” because the plant is already experiencing moments of low health and producing less energy.

Figure 3

From: Rosentiel, T.N., et al. (2004) *Plant Biology* 6: 1-10. This shows the pathway for incoming carbon inside the plant leaf and the release of the carbon as isoprene. The graphic purposes that the enzyme isoprene synthase or G-3P could limit the production of isoprene.



The control plants exhibit a little suppression, which indicates that in more desirable conditions, the plant would utilize the carbon in a more advantageous route to create more pyruvate. These speculations are inconclusive with the data obtained.

The decreased suppression in plants C₁ and C₂ on October 14, 2009 when the temperatures were raised demonstrates a direct relationship between isoprene and temperature. The increase in leaf temperature suggests that isoprene production is not limited by pyruvate, but could be limited by G-3P or the rate of isoprene synthase (see Figure 3). The production of DMAPP is a balance between pyruvate and G-3P, and the balance is not constant with fluctuating temperatures. We are exploring further experiments to test these competing explanations.

Conclusion

The findings from this experiment are not conclusive and more studies must be conducted to determine the relationship between isoprene emissions and the leaf temperature in cottonwoods. The goal for future studies is to gain a more detailed understanding of isoprene modeling. A fuller understanding of isoprene emissions requires that isoprene be examined from a mechanistic approach, in which modeling can predict the isoprene emissions in plants under changing temperatures. A mechanistic approach would reveal the inner workings of a leaf that can answer important questions concerning plant adaptations in changing environments. This method of understanding BVOC production differs from an empirical approach, which provides extrapolations with the given data, but does not detail changes that can occur in the surrounding environment that can impact and influence BVOC emissions. The data gathered from this study highlight that isoprene suppression would be of less importance in an environment experiencing increased temperatures. We are exploring further experiments to test these competing explanations concerning Hypothesis 2.

Acknowledgments

I would like to thank Dr. Mark Potosnak for his guidance, help, and support. I am grateful for Dr. Judith Bramble's advice, the Undergraduate Summer Research Program, and the Illinois Stokes Alliance for Minority Participation scholarship.

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Degradation of Ailanthone, an Allelopathic Chemical Produced by *Ailanthus altissima* (Tree of Heaven)

Reid Gustafson*

Abstract The Tree of Heaven (*Ailanthus altissima*) is known to produce an allelopathic chemical, ailanthone, that prevents the success of other plants. In this experiment an ailanthone extract was prepared and filtered through sterile and non-sterile soil. These extracts and an ailanthone control were analyzed by HPLC each day to monitor its decomposition. The results show that ailanthone decomposes rapidly, losing its original structure in two days and most of its allelopathic activity in six days under all experimental conditions. Filtering the extract through non-sterile soil reduced the amount of ailanthone in solution, but did not affect degradation over time. The rapid decomposition rate is unexpected for a chemical assumed to have an allelopathic function, suggesting that the chemical may have evolved under a different selective pressure.

Introduction

As current agricultural practices make rural Illinois more and more homogenous, urban ecology has become more important. Invasive species in the Chicago area have led to an incredible loss of biodiversity in the natural ecosystem (Dirzo and Raven, 2003). Loss of biodiversity is typically attributed to habitat destruction, but in the Chicago region, most recent threats to biodiversity are due to non-native invasive species (Gordon, 1998). Non-native invasive species are likely to have a high level of fitness because of the lack of natural predators and pathogens that reduce mortality and also often result in superior competitive abilities. Recently, there has been an interest in methods of competition involving chemical interactions (Callaway and Ridenour, 2004). Some plants produce chemicals that have the ability to affect the growth and development of another organism. These allelopathic chemicals give an invasive plant the ability to reduce surrounding competition. This decreases biodiversity and negatively affects the fragile ecosystems that invasive species move into.

Ailanthus altissima is a known invasive species found in Chicago and other urban habitats. It was introduced from China in 1784 for medicinal purposes and as a habitat for silk worms (Heisey, 1996). It is known that *A. altissima* produces allelopathic chemicals that likely contribute to its ecological success (Heisey, 1996). Competitors of the *Ailanthus* tree may be at a disadvantage since they lack adaptations to deal with the allelopathic chemical it produces. This has likely contributed to the success of the *Ailanthus* tree in its new environment.

The allelopathic chemical found in *A. altissima*, identified as ailanthone, influences the growth and development of other plants and causes seeds of other species not to germinate in laboratory tests (Heisey, 1996, 2003). Previous work suggests that ailanthone has an ecological effect on other plant, both native and agricultural, but all the work has been done in a laboratory setting.

Prior research shows that ailanthone breaks down more rapidly in non-sterile than sterile soil (Heisey, 1996). This suggests a role of soil microorganism in either breaking down or using up the chemical. All previous studies on ailanthone use a bioassay to evaluate the chemical's inhibition of seed germination. Bioassays use target seeds, typically radish or lettuce, to assess the impact of the chemical on germination and early growth over that of a water control. There is variability in both seedling response and concentration of the allelochemical. The variation of the subject seeds is controlled by large sample sizes and independent replicates. However, no attempts have been made to evaluate ailanthone concentrations over the course of the experiment, despite reports that the compound is unstable (Heisey, 1996). In response to these methodological concerns, I followed Diallo and Vanhaelen (1991) to isolate ailanthone and then developed a chemical assay using HPLC with UV detection. In addition to providing a more immediate measure of ailanthone, this new procedure allows us to evaluate factors in soil that affect ailanthone and to further explore its ecological properties. The HPLC permits quantitative analysis of ailanthone, providing direct results concerning the presence of the chemical in nature. For the first use of the chemical assay to study the ecology of ailanthone, I tested the

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hypothesis that ailanthone degrades more rapidly in the presence of soil micro-organisms.

Methods

Preparation of Extracts

Roots of an *ailanthus* root sprout were soaked in a water solution containing 5 mL of water for every gram of root. After 30 minutes, the dirt/root material was filtered using 90 mm filter paper. The remaining solution contained ailanthone.

Degradation of Ailanthone

The degradation of the ailanthone was studied by setting up 12 beakers containing ailanthone extracted with water and controls. The soil was sterilized at 121 °C for one hour in an autoclave. The extracts were filtered through sterile and non-sterile soil using a Büchner funnel with vacuum suction. Table 1 gives the overall design of the experiment. These solutions in the beakers were left out on the lab bench and covered with parafilm for the duration of the experiment.

Table 1

Experimental design

Beaker #'s	1, 2, 3	4, 5, 6	7, 8, 9	10, 11, 12
Conditions	Ailanthone extract filtered through sterile dirt	Ailanthone extract filtered through non-sterile dirt	Ailanthone extract	water

Assay of Ailanthone Activity and Concentration

Inhibition of seed germination assay was set up at day 1 and day 6 of the experiment. The assay consisted of five radish seeds in one petri dish for each beaker's extract. One week later, the length of each seedling's primary root (radicle) was measured and averaged for each dish. Every day, 10ul of all 12 solutions were analyzed on a Waters Acuity HPLC outfitted with a 2.1 x 100 mm ACQUITY column BEH C18 1.7 µm using a gradient of 0.1% TFA and acetonitrile as the mobile phase. The peak height for the known ailanthone peak was recorded each day. The ailanthone peak was identified by UV spectrum and retention time relative to an authentic ailanthone standard purchased from Avachem Scientific.

Results

The peak observed for ailanthone in the HPLC was seen at a retention time of 2.33 seconds with an absorbance at 244.6 nm. This was confirmed through comparison with a standard in the HPLC. Figure 1 shows the degradation of ailanthone in the experimental treatments over time in the HPLC.

Figure 1

Overlay of HPLC chromatograms for all six days of experiment

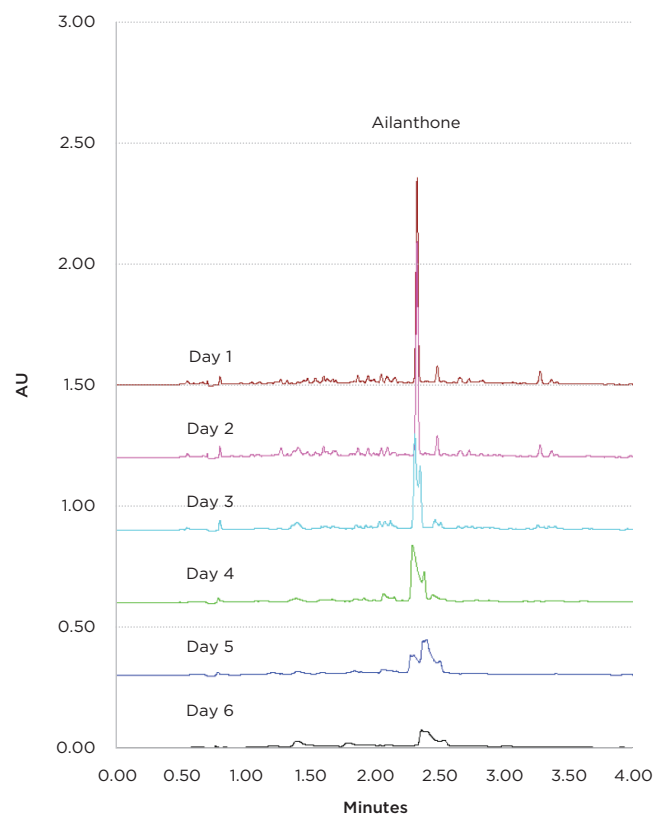


Figure 2 depicts the average peak height of ailanthone for each treatment group over the six days of the experiment. Initially, at day one the non-sterile soil had a lower concentration of ailanthone compared to the other treatment groups. During

Figure 2

Breakdown of Ailanthone (mean+/-SE)

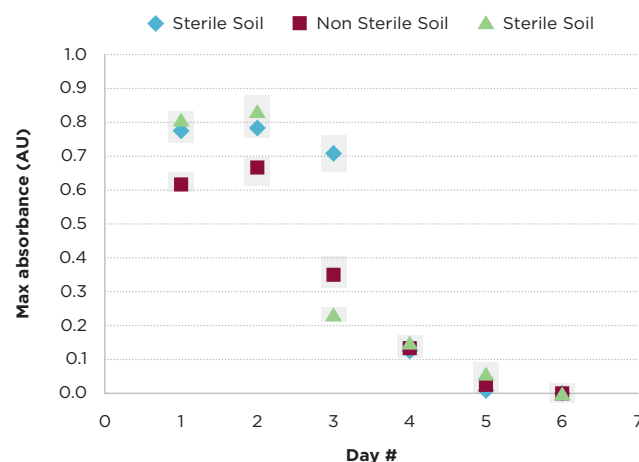
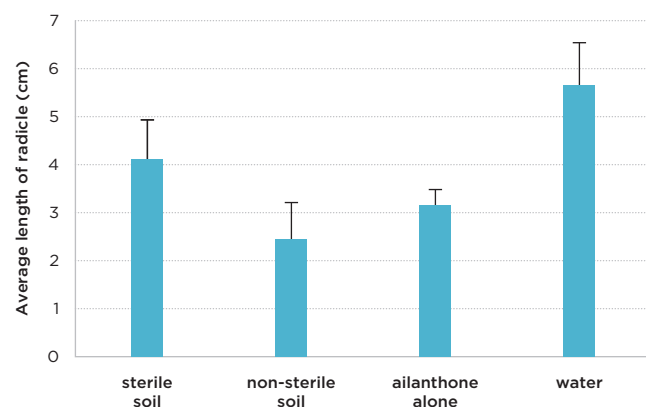


Figure 3

Radicle length from solutions at day 6



the first two days of the experiment the levels of ailanthone did not drop for any treatment groups. At day three the concentration of ailanthone declined sharply and continued until it disappeared in day six.

Inhibition of seed germination was assayed on day one and day six. On day one all experimental groups completely inhibited the germination of the radish radicles. By day six the non-sterile treatment inhibited radish growth significantly compared to water. Figure 3 illustrates the environmental treatment differences, followed by the chemical assay, showing little difference between them.

Discussion

Soil bacteria have the ability to degrade chemicals naturally produced by plants, but this does not appear to be the case for ailanthone. If soil bacteria degraded ailanthone, then the non-sterile soil would show significantly less allelopathic properties by the sixth day, when in fact the opposite occurred. The soil bacteria appear to have no effect on ailanthone, and compared to the water control, the non-sterile solution show more allelopathic activity.

The HPLC chromatograms reveal a clear pattern of degradation of ailanthone. On the first two days, ailanthone is stable in solution, seen in its large peak at 2.33 seconds. But at day three two peaks begin to form at half the height of the original ailanthone peak; this is the start of the degradation process. If retesting occurs, bioassays should be done for each day the HPLC is used.

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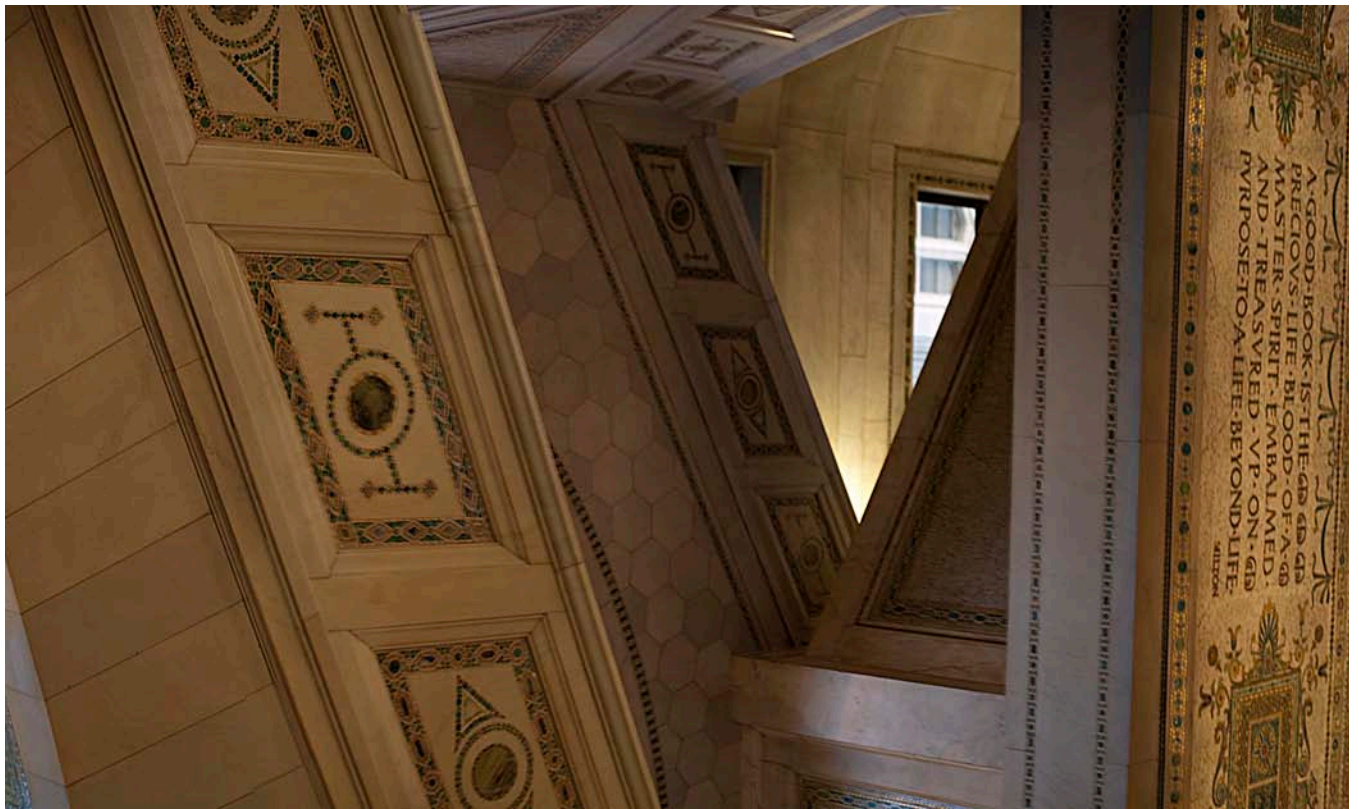
This would tell when the chemical stops becoming allelopathic. On days four, five, and six, the HPLC chromatogram show mostly degradation products of the original ailanthone solution with minimal ailanthone yet some biological inhibition present.

All the experimental groups showed the same pattern of degradation in the HPLC, indicating that the chemical degrades in all conditions of this experiment. The rapid degradation implies that in order for ailanthone to be an effective herbicide, as it was originally thought to be, it would have to be constantly produced by the plant and only be able to affect other plants that are growing in extremely close proximity. For an allelopathic chemical to be ecologically effective it must be able to inhibit the growth of plants that are in direct competition with it. Because *A. altissima's* allelopathic chemical degrades fast it may not be effective as a herbicide, implying another ecological purpose. Previous papers have shown that ailanthone can work as an insecticide, which may be its actual ecological function.

The solution of ailanthone in water gives a hint of its mechanism of degradation. I observed that ailanthone decomposed in a -200C freezer in a solution of methanol and DMSO (data not shown). This prior observation and the results of this experiment suggest that ailanthone breaks down via hydrolysis and not by any organism found in the soil.

Monitoring the degradation of ailanthone provides additional insight into the nature of the chemical, its ecological purpose, and its functions within the plant. This will contribute to an understanding of ailanthone and *A. altissima's* effect on urban ecology. It is unknown if ailanthone actually has an ecological effect on its surrounding organisms. Ailanthone has never been studied in nature and no test has been done to see what happens to the ailanthone once it leaves the plant and enters the surrounding soil. The apparent decomposition of ailanthone leaves it unclear whether it can diffuse far enough in the soil to affect nearby plants. Also, the fact that seed germination was inhibited after ailanthone decomposed raises questions about the true identity of the active allelochemical. These important questions need to be answered in order to have a full understanding of ailanthone. Future experiments can use the new chemical assay to measure the concentration of ailanthone in the natural environment under different environmental stresses and to determine where the chemical is produced and how it moves within the plant.

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Allison Brock
Chicago Cultural Center
Digital Photography

The Effects of Multiple Mycorrhizal Fungi on Perennial Prairie Plants and the Mutualistic Implications

Erika Spencer*

Abstract The mutualistic interaction between a plant and multiple mycorrhizal fungi is a complicated relationship still under investigation. The question being addressed is whether a plant infected by more than one species of fungus affects plant fitness and if any effect is a benefit or cost. If being infected by more than one fungus benefits the plant, are the effects additive or only as beneficial as the better mutualist? We studied this relationship by growing one species of plant in four different treatments: one treatment with *Scutellospora fulgida*, one with *Glomus claroideum*, one with both fungi, and one under sterile treatment conditions. The growth and survival of the plants were measured to determine the effect of treatment. We found that there was both a cost and a benefit associated with mutualistic relationships.

Introduction

Mutualism in nature is a relationship between species in which each benefits. Mutualistic partners provide each other with something they cannot give for themselves, such as nutrients, protection, pollination, and/or other forms of help. Interestingly, in many cases there is an associated cost with this relationship (Bronstein, 2001). What might a partner receive that outweighs what is in some cases an extreme cost? For example, some flowering plants expend a significant amount of energy into the creation of pollinator-attracting tactics, such as nectar. Nectar is a fuel, made of sugar, that could instead be used for the plant. If these relationships cost either partner energy, survival, or other attributes, why participate?

This study investigated the mutualist relationships between mycorrhizal fungi and flowering plants. Mycorrhizal fungi reside in the soil and have hyphae, which infect the epidermal cells of a plant's roots, forming a symbiotic relationship. Symbiosis can be parasitic. However 80% of flowering plant species will form mutualistic relationships with mycorrhizae (Harrison, 1997) where the plant provides the fungi with a carbon-based energy source in the form of sugar and the fungi transfer water and phosphates, which are difficult to obtain from the soil, to the plant. Need can control mutualistic relationships, and a plant with high levels of phosphorus can prevent hosting of mycorrhizae (Harrison, 1998).

While mycorrhizal fungi have been found to be mutualists with most types of flowering plants, the extent to which they benefit the plant varies among plant species and fungi (Bever et

al., 2009). The present research tested the effects of a mutualistic relationship on each mutualist and plant growth. This was done by comparing the effects on growth (roots and leaves) on plants that continued one or two fungi. Four treatments, *Scutellospora fulgida*, *Glomus claroideum*, both fungi species, and sterility, were used to test the effects of infection by different and multiple mycorrhizae. The plant used was *Coreopsis palmate*, a perennial prairie plant that is known to benefit from the presence of mycorrhizal fungi.

Methods and Materials

Soil was collected from Kankakee Sands prairie restoration in Indiana. This site was chosen because the mycorrhizal fungi originate there and it is important for each genotype to be raised in conditions as close to native conditions as possible. The soil was autoclaved twice to insure that it was sterile and mixed with playground sand (Home Depot) to create a 50% soil-sand mixture. The mixed soil was used as both sterile and for the creation of the inoculated soil. The inoculum mixtures were prepared using the mycorrhizal species *Scutellospora fulgida* and *Glomus claroideum*, which were chosen because previous experiments found that they are unequally beneficial to a plant (Bever et al., 2009). Both species were isolated and grown at Indiana University in the lab of James Bever and mixed with sterile soil. One half liter of inoculum was mixed with 2.8 L of soil to create a 15% inoculum mixture.

Seeds from the perennial plant, *Coreopsis palmate* from Spence Restoration in Muncie, Indiana, (collected in 2008), were planted in a flat in metromix, watered and placed in a cold room for cold moist stratification on July 6, 2009. They were removed

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and placed in the greenhouse on July 20, 2009. The plants began to germinate on August 10, 2009.

This experiment used long cone-shaped pots called Deepots (Stuewe & Sons of Tangent, Oregon) that each fit one plant. The pots were filled with three different soil layers to ensure that the roots of the plant and mycorrhizae were in reach of each other. It was expected that the majority of the roots would be located in the middle layer and thus it is the only layer containing inoculum. The layers were calculated based on the total volume of the pots having 185mL on the bottom layer, 130mL in the middle layer, and 210 mL at the top layer. Each pot was fitted with filter paper at the bottom to reduce soil loss. Each contained sterile soil on the bottom layer, followed by a middle layer consisting of inoculated or sterile soil, depending on which treatment the pot received. One plant and a final layer of sterile soil were placed in each pot.

After watering each plant, the pots were all placed in the greenhouse to grow for 12 weeks. The plants were separated into 10 blocks, with each block containing two plants of each treatment (*S. fulgida*, *G. claroideum*, both, or sterile), except for two blocks, which each had two extra plants. The pots were divided into blocks to prevent any artificial replicates caused by location in the greenhouse and other factors. The first five blocks were planted and placed in the greenhouse 37 days after germination, and the remaining five blocks were completed 43 days after germination. The plants were watered with 30 mL twice a day and received 30mL of fertilizer (Jack's Professional No Phosphorus 20-0-20) every week. The greenhouse conditions were set up to mimic the conditions of spring in Indiana or Illinois. During the day the temperature was set from 72-78 °F, and at night temperatures ranged from 66-72 °F. Lights were set for 16 hours of daylight and 8 hours of darkness.

The growth and survival of the plants were measured three times. The first measurement was the day they were planted and placed in the greenhouse. The second measurement occurred on the 99th day after germination, and the third was 113 days later. On the 115th day the plants were no longer watered and were removed from the greenhouse to allow them to dry in preparation for harvesting. Harvesting took place 8 to 17 days later. It involved separating the roots, leaves, and soil into three different bags. The soil was set aside to measure the growth of the Mycorrhizal fungi in future research.

The roots and leaves were dried in the drying oven and weighed on an analytic balance. The mass of the roots and leaves paired with the growth and survivorship of the plant was then used to statistically determine the effect of treatment on plant fitness.

Statistical Analysis

The leaf weight was log-transformed to more normally distribute the variance and analyzed using an Analysis of Variance (ANOVA) with treatment as a fixed factor and survival of plants at the midpoint of the experiment and the initial height of the plant as a covariate. The final weight of roots was analyzed using an ANOVA, with treatment, block, initial size, and survivorship at the midpoint of the experiment as fixed factors. The height of plants at the midpoint of the experiment was tested using an ANOVA, with treatment and block as fixed factors and initial height as a covariate. The final height of the plants was analyzed using an ANOVA, with treatment and block as fixed factors and initial height as a covariate. The survivorship of the plants was analyzed using General Linear Modeling (GLM), with treatment and block as fixed factors, and treatment X block as an interaction effect. I used the Tukey test to determine which treatments were different. Analyses were done using SPSS 15.

Results

This study attempted to determine if the presence of multiple mycorrhizal fungi makes a difference on plant fitness. A plant with fungi could be expected to do better in the presence of fungi than without. Whether the affect of multiple fungi species is more beneficial than only one species, or only as beneficial as the better mutualist, is yet to be determined.

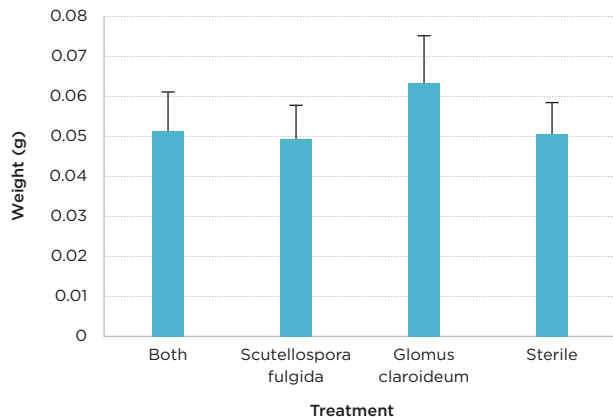
The effect of infecting a plant with multiple fungi on plant growth was measured by comparing the outcome of treatment on several different factors that affect a plant's overall fitness. The growth of the plant in centimeters from the starting point to the midpoint to final measurement was examined, as well as the effects on the weight of the entire plant, the roots, and the leaves. The plants did not reach a point where they produced seeds, so that factor could not be considered, though larger plants are assumed to have greater reproductive success.

Treatment was found to have an effect on the leaf weight of plants ($F=2.871$, $df=3$, $p=0.043$). The size or number of leaves was affected by the infection of mycorrhizal fungi. The plants infected with *Glomus claroideum* were found to have the greatest average leaf weight. Treatment, however, did not have a significant effect on the root weight of the plants ($F=0.446$, $df=3$, $p=0.721$). The growth of the roots was similar under all the treatments.

Treatment had no effect on height at the midpoint measurements ($F=0.360$, $df=3$, $p=0.782$). Nor was there an effect of treatment on the final height of the plants ($F=1.746$, $df=3$, $p=0.165$). Whether or not a plant was infected with fungi did not determine plant growth. The most important factor on plant growth was the initial size of the plant.

Figure 1

The effect of treatment on the mass of leaves produced by a plant shows that the treatment of *Glomus claroideum* produces the largest average weight of leaves.



The effect of treatment on survivorship at the midpoint was significant ($F=2.526$, $df=3$, $p=0.070$). The Tukey test revealed a significant difference between the sterile treatment and the treatment with both fungi ($p=0.081$). A higher percentage of plants died in the treatment with both fungi than with the sterile treatment. Treatment had no effect on survivorship at the final point of measurement ($F=1.819$, $df=3$, $p=0.158$); if a plant lived past the midpoint treatment, treatment no longer had a significant effect on survival.

Discussion

The outcomes found were unexpected. A previous experiment found *Scutellospora fulgida* to be a better mutualist than *Glomus claroideum* (Bever et al., 2009). But in this case, there is no evidence that *Scutellospora fulgida* was any more beneficial than any other treatment. This finding is interesting because it is the opposite of what was expected. As a better mutualist, *Scutellospora* was expected to be the most beneficial. Instead, we found that *Glomus* had the greatest effect on the height of the plants and the sterile treatment had the highest rate of survival.

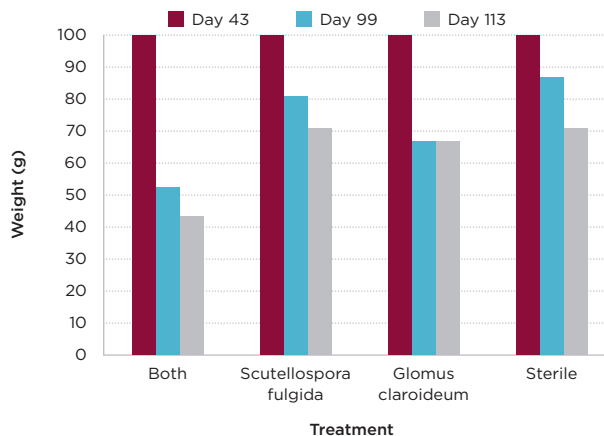
These results may have been connected to the stress experienced by the plants of being raised unnaturally in a crowded flat and then transplanted as individual plants. This may have been a factor in the high death rate experienced among all treatments

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Figure 2

The effect of treatment on survivorship shows that at day 99 the treatment with both fungi had the highest rate of mortality and the sterile treatment had the highest survival. While the number of plants surviving continues to go down by day 113, this change is not related to treatment.



within the first few days. The drastic reduction in the sample size that resulted made many statistical tests impossible.

This finding may have implications for the evolution of plant species as generalist or specialist. Plants can control mutualist relationships when they have high levels of phosphorus. This type of variation may also relate to the effectiveness of a mutualist in different situations. Under normal stress, a plant benefits greatly from one species of fungi, but under high stress that presence becomes costly. This may indicate a plant's need for different species of mycorrhizae under different conditions. If this experiment is repeated in the future, a larger sample size should be used to allow for the inevitable death of plants in the stress transplant process, and to compare the effects of stress at different stress levels.

The next step of this evaluation would be to determine the effect of multiple mycorrhizae on the growth of fungi. Is the growth of the fungi affected? This will be determined by examining the soil and the infection rates of the roots.

Acknowledgments

I'd like to thank Dr. James Bever, Stephanie Hughes, Corey Palmer, Hemal Patel, and Jake Schintgen for their help in the set-up of this experiment. I'd also like to thank Dr. Matt Enos, Dr. Marci Enos, Corey Palmer, and Dr. Sarah Richardson for their comments that helped improve this manuscript.

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Andy Siharath
Nature vs. Architecture
Digital Photography

The Effect of Mycorrhizal Fungi on *Plantago virginica* in Drought Conditions

Hemal Patel*

Abstract Arbuscular mycorrhizal fungi are beneficial soil fungi present in prairie soil but damaged in abandoned farmland. Our goal for this research is to investigate whether mycorrhizal fungi can help with the restoration of native prairie plants by increasing the health of prairie plant life. We focused on the effects of mycorrhizal fungi and its mutualistic relationship with *Plantago virginica*. We looked at the effect of different mycorrhizae bacteria on the growth of the *Plantago virginica* between drought and no- drought conditions and sterile and non-sterile soils. *Plantago virginica* is a secondary succession plant that grows well within the ecosystem and can thrive within its biome with the help of mycorrhizae. The mycorrhizae fungi may boost the growth, survival rate, and reproduction of *Plantago virginica* which may help this plant to succeed in all restoration efforts.

Introduction

Prairie plant life native to Illinois is a part of an important ecosystem that is falling subject to rapid destruction, leading to the loss of vast lands full of biodiversity. A prairie is defined as an ecological community that has less than one tree per acre. It is grassland dominated by grasses and forbs with various grasses determining the structure of the prairie (Prairie Defined, 1993). One of the most interesting facts about the prairie is that most of its bio content is below ground in the root layer. This is one reason why our experiment focuses on roots and their relationship with the fungi in the soil. We are using the arbuscular mycorrhizal fungi because many species depend on mycorrhizae to supply them with nutrients from the typically infertile soils on which ecosystems develop. The mycorrhizal fungi are critical to retaining nutrients within the prairies. If the prairie is cleared and burned to develop new agricultural lands, much of the nutrient capital of the land is lost due to the reduction of growing biomass, including the destruction of much of the mycorrhizal fungi by the disturbance (Raven, 2003). The fungi that manage to survive are not necessarily appropriate symbionts for the species of grasses and other crops that farmers attempt to grow on the cleared land (Raven, 1998). For some plant species, the association with mycorrhizal fungi is indispensable. The degree of dependence varies with plant species, particularly the root morphology, and the conditions of soil and climate. Plants with thick roots, poorly branched and with few root hairs, are usually more dependent on mycorrhizal for normal growth and development (Atlas, 1987).

The soil borne hyphae take up nutrients from the soil solution and transport them to the root. By this mechanism, mycorrhizal increases the effective absorptive surface area of the plant. In research done on perennials prairie plants with nutrient-poor or moisture-deficient soils, nutrients taken up by the fungi hyphae can lead to improved plant growth and reproduction.

We are interested to see if this effect of mycorrhizae hyphae improves plant growth and reproduction of prairie annuals in nutrient-poor and moisture-deficient soils.

We are investigating whether mycorrhizal fungi had an effect on the plant growth, and if the conditional mutualism between plants and the mycorrhizal fungi is beneficial. In conditional mutualism, plants and fungi exchange beneficial nutrients to each other for the purpose of growth and development. Mutualists such as mycorrhizal fungi are important to restoration and preservation as an organism for native plant species. The mutualistic relationship can help with the creation of phytohormones which allow plants to produce hormones for the production and development of plant parts - flowers, leaves, and roots. The benefits mutualists give may depend on abiotic conditions in the environment. We explored the context-dependency of benefits to plant- growth, survival, and reproductive success in a greenhouse experiment. Our experiment used water treatment to find if high and low water availability will have affect inoculation by the mycorrhizal fungi. The effect of the hyphae from the fungi will provide nutrients to the plant by using the water from a larger volume of soil. We predicted that all species will have an effect with the fungi in drought and non-drought conditions, that the effects of the fungi will aid the plants in reproduction and growth. The species we used for our experiment are native to the Midwest re-

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gion and the soil, fungi, and seeds were collected from Kankakee sands in Newton County, Indiana. *Plantago virginica* is in the *Plantaginaceae* family and is a native prairie weed found throughout the Midwest. It is a secondary succession plant that grows well throughout its native ecosystem.

Methods

In an experiment within the greenhouse we evaluated the benefits of mycorrhizal fungi in prairie species by measuring the height, length, weight, and number of fruit along with survival count of each *Plantago virginica*. We placed half the specimen in drought to ascertain if the plants benefit from the mycorrhizal fungi in drought and non-drought conditions. Seven species were divided into two different treatments, inoculated and non-inoculated. This was replicated eight times for growth rate, then divided by two different water treatments, drought and non-drought: this was replicated an extra one and a half times to harvest six pots for roots and six for spores, totaling 336 pots for seven species. There were 48 pots for each species. Pots were set up in a greenhouse separated into 12 equal blocks on four lab benches, with 84 pots per bench. The azalea pots we used totaled 545 milliliters. We divided the soil into three layers: the first layer was a half and then a quarter cup of sterile soil, the second layer a half cup of inoculation for the middle layer, or sterile if for non-infected pots, the final top layer of 210 milliliters of sterile soil. The pots were then separated and labeled with white tags for non-drought and yellow tags for drought.

Sandy soil from Kankakee Sands was used for the sterile and non-sterile soil. We used the autoclave to sterilize the soil and remove soil microorganisms. With the autoclaves we can neutralize potentially infectious agents by utilizing pressurized steam and superheated water. The mixed inoculum was made up of *Glomus mosseae*, *Glomus claroideum*, and *Scutellospora fulgida*. Three hundred milliliters of *Glomus claroideum* had been chopped and frozen along with 500 milliliters of *Scutellospora fulgida*. A total of four liters of inoculum was used for the main prairie drought experiment. The plots the seeds were collected from are near the Newton County, Kankakee Sands nursery and greenhouse. Seeds for the prairie plants were started in sterilized Metromix and then transplanted individually into the pots and moved into the cold room on July 6, 2009.

We conducted a factorial experiment to investigate the effect of inoculation by mycorrhizal fungi under conditions of high and low water availability. The data were collected and analyzed using statistical data software and SPSS to show the effects of the mycorrhizae. We conducted an Analysis of Variance (ANOVA) to determine the statistical differences among the treatments on

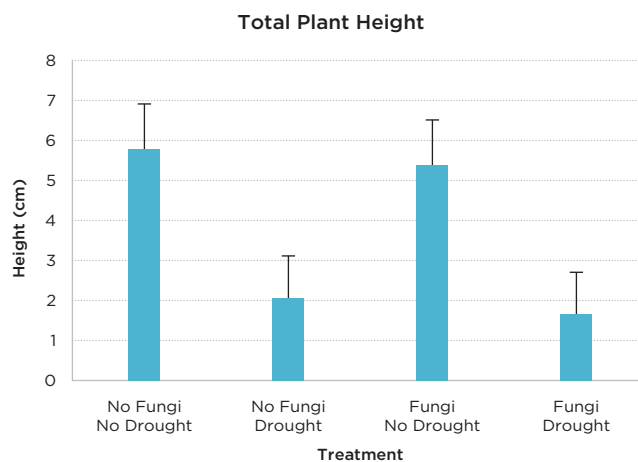
the species and a general linear model to find the different effects of the inoculum.

Results

We had predicted that the effects of mycorrhizal fungi on the prairie plants would vary from neutral to beneficial, and that contexts effects would depend on the plant species. The *Plantago virginica* did not benefit from mycorrhizal fungi under either high or low water availability. Other species only benefited under conditions of low water availability, indicating that the benefits were context-dependent. Our results suggest that mycorrhizal fungi may not be as important to the restoration of *Plantago virginica* as it is to other native prairie plants. The fungi did not affect the total plant size; plants with and without the fungi grew to about the same height ($f_{d}=5.833$, $f_{nd}=5.433$), while plants under different water conditions proved to be affected by drought. The total plant weight was not affected by the inoculum and inoculum showed no significant effect on the total plant size and weight. Block and drought were the two only factors that produced significant differences in the growth and health of *Plantago virginica*. Block effect is the random placement of plants throughout the greenhouse. Some plants had the variability of placement and growth was affected by the random placement. Figure 1 compares the different treatments and different soil inoculations. There is a little to no difference in the amount of growth for the soil and water treatments. Mycorrhizal fungi has no effect on *Plantago virginica*.

Figure 1

Standard Error column graph for total plant weight in both water treatments and for sterile and non-sterile soils.



Discussion

The comparison of total plant growth and weight between sterile and non-sterile soil in drought and non-drought conditions proved to have very little overall significance on the growth of *Plantago virginica*. Being a primary succession plant it is more suitable for growth and colonization in prairie restoration. Since *Plantago virginica* utilizes the nutrients within its environment to the utmost potential, the mycorrhizal may have a slight benefit because the plant itself is very successful in growing the fungi.

Acknowledgements

I am truly grateful to Dr. Sarah Richardson for her dedication and assistance during this experiment, I am also very thankful that she gave this opportunity to work on her research team. I would also like to thank the DePaul College of Liberal Arts and Science Undergraduate Research Program and the Louis Stokes Alliance for Minority Participation (LS-AMP) for granting me the funds to complete this research.

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The Effect of Mycorrhizal Fungi on Annual Prairie Plants in Drought Conditions, with a Focus on *Plantago aristata*

Stephanie Hughes*

Abstract Mycorrhizal fungi are known to have a mutually beneficial relationship with perennial prairie plants based on previous experiments (Bever, 2010). This experiment tested to see if mycorrhizal fungi have the same relationship with annual prairie plants. Some of the replicates were grown in drought conditions to see if mycorrhizal fungi benefit the plants more when water availability is decreased. Although the entire experiment included five annual prairie plants and two perennials, this paper only focuses on one annual species, *Plantago aristata*. Mycorrhizal fungi were found to generally have no effect on the growth or survival of *Plantago aristata* and very little effect on its reproduction.

Introduction

Many different species of plants, animals, and insects are only found in the prairie. With the rapid destruction of prairies, we are losing the only land where these species can survive. One of the most interesting facts about the prairie is that as much as 65 percent of its biomass is underground in the root layer (Miller, 2005). The plants that grow in the prairie have strong root systems that are very thick and extend deep into the ground. This is one reason why this experiment focuses on roots and their relationship with the fungi in the soil. Fungi that grow in plant roots are used in this experiment because previous experiments have shown that they benefit prairie plants (Miller, 2005). These fungi, specifically mycorrhizal fungi, grow inside the roots of the plants and the soil, helping the plants increase their capacity to absorb water and nutrients from the soil. In exchange, the plants provide fungi with soluble carbon sources (Entry et al., 2002). This interaction between species that exchange benefits is called a mutualism.

There has been a lot of work recently to restore prairies from old fields. Restoring prairies is very difficult; one study shows that only about half the diversity living in natural prairies survives in restorations (Martin et al., 2005). This research investigates whether plants benefit from mycorrhizal fungi. If so, adding mycorrhizal fungi may improve the success of prairie restorations. Because restored prairies are susceptible to drought, this research also investigated whether mycorrhizal fungi benefits plants more under drought conditions. If the prairie plants benefit under drought conditions but not with normal water treatments, it is conditional mutualism, meaning that it is only beneficial under

certain conditions. This experiment was conducted to answer the following questions: Does adding mycorrhizal fungi to the soil benefit annual prairie plants? If the plants are grown in drought conditions, are the benefits increased? The prediction was that plants grown in soil containing mycorrhizal fungi would benefit more than plants without mycorrhizal fungi, especially when grown in drought conditions. The benefits to plants were measured by their survival, growth, and reproduction.

Although this paper focuses on *Plantago aristata*, the experiment included four other annual prairie plants and two perennials. The other annuals were *Aristida intermedia*, *Oenothera laciniata*, *Potentilla norvegica*, and *Plantago virginica*. The two perennials, *Agrostis hyemalis* and *Coreopsis palmata*, were used as controls for comparison because previous experiments have found that perennials benefit from mycorrhizal fungi (Bever, 2010).

Methods

The seeds, soil, and fungal genotypes were collected for the experiment from Kankakee Sands in Indiana, which is a prairie owned by The Nature Conservancy (TNC). The area where TNC decided to grow a prairie was previously a lakebed that was drained many years ago, so the soil is very sandy (Lucas, 2005). To begin the experiment, the *Plantago aristata* seeds were collected from Kankakee Sands in summer 2008. Seeds were germinated in autoclaved Metromix in previously sterilized flats. The flats were thoroughly soaked watered and placed in a cold room for two weeks to undergo cold-moist stratification. After two weeks, the flats were placed in the greenhouse at DePaul University until the seeds germinated.

To increase drainage in pots, soil collected from Kankakee Sands was mixed in a 1:1 ratio with Premium Play Sand from

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Home Depot. This soil/sand mixture was then autoclaved twice for two hours at 121°C to sterilize it and kill any mycorrhizal fungi originally present in the soil. The inoculum, soil that contains chopped roots infected with mycorrhizal fungi, used in this experiment was a mixture from three different collections, each containing one or all of the following species: *Glomus mosseae*, *Glomus claroideum*, and *Scutellospora fulgida*. Altogether, 4200 mL of inoculum was used, which was then mixed with 23.1 L of the sterile 1:1 sand/soil mixture (from now on referred to just as soil).

Since this experiment was designed to test the relationship of mycorrhizal fungus and drought on prairie plants, it was set up with four pots of plants in each block. Each pot had three plants. Twelve blocks were spread across four greenhouse benches to minimize the effect of variability in the results due to varying amounts of sunlight hitting the benches.

Pots were filled and planted under sterile conditions to reduce contamination. One Whatman #1 8.5 cm filter paper was added to the bottom of each pot to prevent the soil from spilling out. The soil in each pot was divided into three layers: the bottom layer contained 185 mL of sterile soil; the middle layer contained either 130 mL of inoculum or sterile soil, depending on which treatment it was for; and the top layer of the pot was filled with 210 mL of sterile soil. Inoculum was placed in the middle layer to prevent spread to non-infected pots and to maximize contact with plant roots. Once the three layers of soil were in the pot, plants were pulled from sterile flats and planted in each pot using a sterilized glass rod. The pots were placed within each block using a random number generator, to make sure that conditions within the greenhouse affected each treatment equally. A bacterial wash was added to remove any possible difference in bacteria. This was created by mixing non-sterile soil from Kankakee Sands with water. A sieved soil and water mixture was vacuum-filtered and the liquid collected. 12 mL of this bacteria solution was poured on every pot one week after the first measurements were taken.

Immediately after planting, all pots were watered with 45 mL of water once a day. The drought treatment began 24 days later, which meant that supplemental lights in the greenhouse were kept on 16 hours a day. At that point, plants in the non-drought treatment were watered twice a day with 45 mL of water and plants in the drought treatment were watered twice a day every three days. Two weeks after planting, all the plants were fertilized twice. After that, they were fertilized once a week. 125 ppm of John's Professional No P 20-0-20 fertilizer in 45 mL of water was used because mycorrhizal fungi do best in low phosphorous soil.

A week after planting, the first measurements of growth were taken. For *Plantago aristata*, the length of the longest leaf was

measured. The plants were measured for the second time 24 days after the last block was planted. Besides the length of the longest leaf we recorded whether each plant was alive and flowering. The plants were measured for a third and final time about one month after the second measurements were made. Besides the length of the longest leaf, we measured the number of fruit per plant and the length of flowering heads to determine reproductive success.

After all the final measurements were taken, the plants were harvested. Because harvesting could not be done in one day, a minimum of all four pots of one species in a block were harvested on the same day. Harvesting consisted of cutting off all fruits and placing them in a bag for drying. The plants were rinsed in a sieve to cleanse the roots free of soil and filter paper as much as possible. The leaves were separated from the roots and placed in separate bags for drying. A small sample of roots from each pot was placed in labeled cassettes for staining later.

Once all plant parts were dry and would not be affected by the weight of water, the fruit, roots, and leaves from each pot were weighed separately using the Mettler Toledo balance. When the final data was analyzed at the end of the experiment, each pot was considered one replicate by using the total amount of growth, weight, or survival of all three plants in the pot. All the results were analyzed using Analysis of Variance (ANOVA) in SPSS. We used a log transformation of the data to analyze the total weights of roots and leaves. For the analysis of total fruit weights, we used a square root transformation of the data. The ANOVA of total fruit lengths included the covariate of midpoint length measurements of the plants.

Results

To show what affected *Plantago aristata* and how much, we conducted different analyses of growth, reproduction, and survival. Growth was represented in analysis in two different ways: the dry weights of roots and leaves together and the final length of the leaves. Adding mycorrhizal fungi did not increase the dry weight of the plants ($F_{1, 18} = 1.046; p = 0.320$). However, the block affect ($F_{9, 18} = 3.281; p = 0.015$) and water treatment ($F_{1, 18} = 117.814; p < 0.0001$) both had an effect on the dry weights of the plants. The added mycorrhizal fungi had no effect on the final leaf lengths either ($F_{1, 34} = 0.350; p = 0.558$; Figure 1). However, drought conditions ($F_{1, 34} = 68.301; p < 0.0001$; Figure 1) and block ($F_{11, 34} = 3.285; p = 0.004$) had an effect on the final length of the leaves. The block effect explains differences in the time and day each block was planted, sunlight variability in the greenhouse, and time of harvest. The water treatment's effect on the growth of the plants shows that the plants grew better in non-drought conditions in both dry weight and final leaf length measurements.

Figure 1

Growth Comparison of Effects of *M. fungi* Over Time. The total longest leaf length measurements from each replicate were averaged for each treatment, for each of the three measurement times for *Plantago aristata*. The graph shows that plants grown in non-drought conditions grew leaves about the same length, regardless of the presence of mycorrhizal fungi. In drought conditions, the plants all showed decreased growth, and plants grown in sterile soil grew slightly longer leaves than plants infected with mycorrhizal fungi. At the midpoint, the plants infected with mycorrhizal fungi did not grow as much as plants grown in sterile soil. This demonstrates a negative relationship between the plants and the fungi. Plants subject to drought started getting watered less the same day the midpoint measurements were taken.

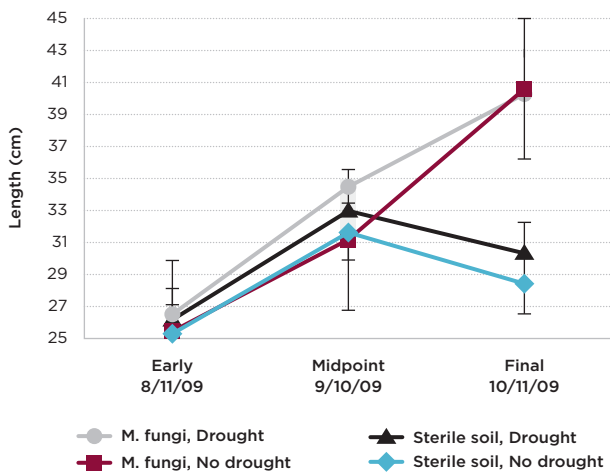
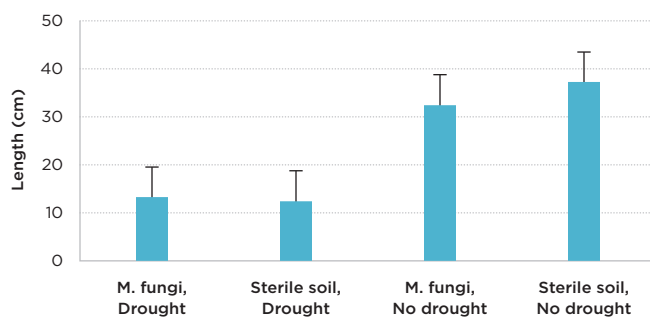


Figure 2

Average Total Fruit Length of Each Treatment. The total fruit length data for each replicate was averaged for each treatment. In drought conditions, *Plantago aristata* grew longer fruit in soil containing mycorrhizal fungi than in sterile soil, but in non-drought conditions, the plants grew longer fruit in sterile soil. getting watered less the same day the midpoint measurements were taken.



The length of the fruit produced on each plant is a measure of reproductive success because it shows whether the plant put a lot of energy into growing the fruit for reproduction. Mycorrhizal fungi had a minor effect on the fruit lengths of the plants ($F_{1, 32} = 3.187; p = 0.084$; Figure 2). The water treatment had a significant effect on the lengths of the fruit ($F_{1, 32} = 173.759; p < 0.0001$; Figure 2). The plants grown in non-drought conditions grew longer fruit than those grown in drought conditions. The interaction of mycorrhizal fungi and water treatment also had a significant effect on fruit length ($F_{1, 32} = 4.100; p = 0.051$; Figure 2). In drought conditions, plants infected with mycorrhizal fungi grew longer fruit; in non-drought conditions, plants in sterile soil grew longer fruit than plants infected with inoculum.

It is hard to say from this experiment whether mycorrhizal fungi have an effect on the survival of *Plantago aristata*. All replicates grown in drought and non-drought, with and without mycorrhizal fungi survived.

Discussion

This experiment predicted that mycorrhizal fungi would benefit *Plantago aristata*, and that these benefits would increase when the plants were grown in drought conditions. However, the results of this experiment go against the predictions. The results show that mycorrhizal fungi generally have no effect on the growth or survival of *Plantago aristata* and very little effect on reproduction. Even when the early and midpoint size measurements were included as covariates, mycorrhizal fungi did not show an effect on the growth of the plants.

Although adding the midpoint size measurements as a covariate caused mycorrhizal fungi to show a slight effect on the fruit length measurements, it was not the predicted effect. The prediction was that *Plantago aristata* would grow stronger when infected with mycorrhizal fungi, and that the plants grown in drought conditions would grow stronger when infected with mycorrhizal fungi compared to those grown without mycorrhizal fungi. However the results show that considering the size of the plants at the midpoint as a factor, the plants grown in drought conditions in the presence of mycorrhizal fungi produced shorter fruit than those without mycorrhizal fungi in drought conditions. The non-drought results of fruit length support the predictions because plants grown in non-drought conditions in the presence of mycorrhizal fungi produced longer fruits than plants without fungi. The effect of the water treatments was also different than expected. The results show that plants grown in drought conditions produced longer fruit than plants grown in non-drought conditions.

Although the results were not as predicted, we gained important information from this experiment. *Plantago aristata* overall did not benefit from the presence of mycorrhizal fungi in the soil, and was in some areas even hindered by its presence. It tells those doing prairie restorations not to use soil inoculated with mycorrhizal fungi if they want to include *Plantago aristata* in the prairie. This experiment may also show that mycorrhizal fungi do not benefit annual prairie plants as they do perennials. Mycorrhizal fungi are known to help plants absorb water; the results from this experiment show that this mutual relationship is not affected by water availability.

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The Effect of Genistein plus Estradiol on Apoptosis

Kevin J. Peine*

Abstract Our previous results have shown that low concentrations of genistein, a soy component, inhibit the cell proliferation of ER β breast cancer cells in the presence of physiological concentrations of 17 β -estradiol. These results are especially relevant in premenopausal women with breast cancer of the ER β -negative and ER β -positive type. The aim of the present study was to identify the mechanism by which genistein plus estradiol inhibits the cell proliferation of ER β breast cancer cells. For this purpose, the effect of low and high concentrations of genistein in the presence or absence of estradiol was studied on apoptosis and the expression of the cell signaling protein BAX, involved in apoptosis, in MDA-MB 231 breast cancer cells. Apoptosis was determined by the use of acridine orange and ethidium bromide dyes and the expression of BAX by western blotting and immunodetection. The results indicate that 1QM genistein plus 10-9M estradiol increases apoptosis ($p < 0.05$) as compared to the control (12.47% vs., 5.87% respectively). In parallel, an increase in the expression of BAX (2.5 fold) was observed in cells treated with low concentrations of genistein plus 17 β -estradiol as compared to the control cells. High concentrations of genistein (100 QM) in the presence or absence of 17 β -estradiol also increased apoptosis and decreased cell proliferation; however, these changes could not be correlated to the expression of BAX. In conclusion, low concentrations of genistein in the presence of 17 β -estradiol probably inhibit cell proliferation through apoptosis via an increase in BAX expression. Our results also suggest that different concentrations of genistein elicit cell responses through different mechanisms.

Introduction

According to the American Cancer Society, breast cancer is the second leading cause of cancer-related death in women from the United States where it is estimated that 1 in 35 women will die from breast cancer (1). Cancer is characterized by uncontrolled cell proliferation and the ability of cells to invade surrounding tissues. The evasion of programmed cell death or apoptosis is a hallmark of cancer cells and could be one of the causative factors leading to uncontrolled cell proliferation. Healthy cells maintain a balance between apoptosis and cell proliferation to achieve a population of healthy cells within the body. However, in cancer cells the balance shifts towards uncontrolled cell proliferation. Apoptosis and cell proliferation are regulated by internal signaling molecules that cause the cell to choose either cell proliferation or apoptosis.

Genistein is a phytoestrogen derived from soy beans that has shown promise as an anti-cancer compound (2). Our lab's previous study also revealed that genistein (1 μ M) plus physiological concentrations of estradiol inhibits cell proliferation in Estrogen Receptor (ER)-beta positive (ER β +) cells by approximately 40%

and stimulates the proliferation of ER-alpha ER-beta positive (ER α +, ER β +) cells (3). Another previous study showed prognosis for ER-beta positive breast cancer cell patients to be worse if the cells were also ER-alpha negative instead of positive (4). Estrogen causes breast cells to proliferate by inducing gene transcription, hence aiding in breast cancer development. An increase in ER-alpha positive cells and a decrease in ER-beta positive cells provide a patient with a better prognosis with certain antiestrogen treatments (4).

The current project was carried out to determine the mechanism by which low concentrations of genistein (1 μ M) plus estradiol inhibit breast cancer cell proliferation. The effect of genistein plus estradiol on apoptosis, along with the presence of the internal proapoptotic cell signaling molecule BAX, was determined. The breast cancer cell line MDA-MB 231 (ER α -, ER β +) was used, based on its ER status and genistein's higher binding affinity to ER β than ER α .

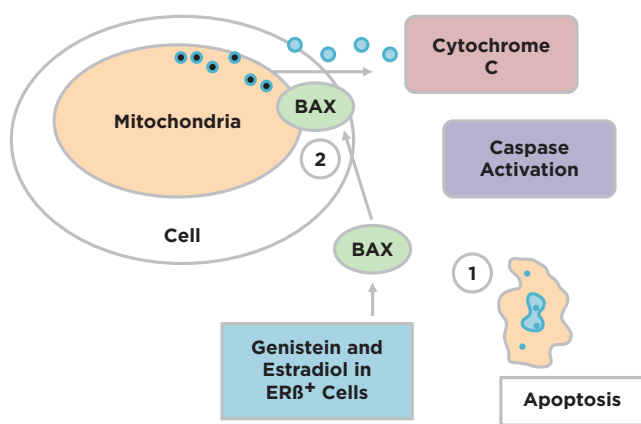
The first objective was to observe the effects of genistein plus estradiol on apoptosis in the MDA-MB 231 cell line. The second objective of this study was to determine the effect of genistein plus estradiol on the internal cell signaling molecule BAX. BAX (Fig. 1, #2) is a pro-apoptotic protein. When activated, BAX activates executioner caspase enzymes that carry out apop-

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tosis (Fig. 1 #1). This study was aimed at identifying whether an increase in the levels of BAX and apoptosis could be correlated to genistein plus estradiol exposure to MDA-MB 231 cells. The present study found that low concentrations of genistein plus estradiol induce apoptosis via the BAX signaling pathway, but high concentrations of genistein likely induce apoptosis through an alternate signaling pathway.

Figure 1

Schematic Mechanism of BAX Activation Facilitating Caspase-Induced Apoptosis in MDA-MB 231 Cells



Methods

Cell Culture: Cells were grown in-vitro through the method of cell culture. The MDA-MB 231 breast cancer cells were obtained from the American Type Culture Collection (ATCC; Manassas, Virginia). The cells were grown routinely as a monolayer culture in RPMI 1640 media (without phenol red). This was supplemented with 2 mM L-glutamine, gentamicin (50 µg/ml), penicillin (100 U/ml), streptomycin (100 µg/ml), and 5% fetal bovine serum. Glutamine and fetal bovine serum were added to provide an environment conducive to the growth of cells. The penicillin and streptomycin were used to prevent bacterial contamination. The cells were incubated at 37°C with 5% CO₂ and 95% humidity.

Estrogen Starvation and Exposure of Cells

The cells were seeded in 100 mm Petri dishes and estrogen starved for a minimum of 24 hours. Following the starvation period the cells were exposed to genistein (1 µM and 100 µM) in the presence or absence of physiological levels of estradiol (1 nM) for 24 hours. The adherent cells were then trypsinized to detach them from the Petri dishes and collected in RPMI 1640 media.

Apoptosis Assay

The apoptosis assay was performed to study the effects of genistein plus estradiol on apoptosis. This method uses features such as the integrity of the cell membrane and fragmentation of the nuclei to determine if the cells are going through an apoptotic cycle. Apoptotic cells stain red and healthy cells stain green. The concept behind the cells fluorescing a different color when going through apoptosis is fairly simple. Ethidium bromide and acridine orange, the two dyes used in this assay, are both fluorescing compounds. Ethidium bromide is considerably larger than acridine orange. Acridine orange is small enough to get through the cell membrane of a viable cell, allowing it to fluoresce green under the microscope. During apoptosis, though, the membrane of the cell starts to break down and lose integrity. This loss of integrity allows the larger ethidium bromide molecule into the cell, changing its fluorescence to red. The assay was performed as follows. To 250 µl of the seeded, starved, and exposed cell suspension, 10 µl of 1:1 ethidium bromide to acridine orange mixture was added. The cells were placed in the dark for 10–15 minutes and 5 µl of the stained cell suspension was placed on a slide, and covered with a coverslip. The cells were then examined using a fluorescence microscope and a green filter. The viable cells were indicated under the microscope by a green glow and the apoptotic cells were red. Analysis was carried out to compare the percent of apoptotic cells under different treatment conditions as compared to the control. Apoptosis was quantified by counting cells in at least 10 fields to achieve a minimum of 250 cells. These cells were counted as either apoptotic or viable and the percentage of apoptotic cells was calculated using the formula: (# apoptotic cells / total cells) x 100.

Western Blotting and Immunodetection

The second objective of the study was to examine the effect of genistein plus estradiol exposure on the internal signaling molecule BAX. The Western Blot method followed by immunodetection allows for the identification of proteins in a cell extract by the use of antibodies. After estrogen starvation, MDA-MB 231 cells were exposed to either 1 µM genistein, 1 µM genistein plus estradiol (1 nM), 100 µM genistein, or 100 µM genistein plus estradiol for 30 minutes. The cells were lysed with 0.5 ml of homogenization buffer (20mM HEPES, pH 7.4, 1% Nonidet P-40, 2 nM, EDTA, 10 µM leupeptin, 10 µg/ml aprotinin, 1.5mM pepstatin, 1mM phenylmethylsulfonylfluoride).

The concentration of the proteins was determined and 50 µg of each sample was loaded into the gel, electrophoresed, and transferred to Polyvinylidene Fluoride (PVDF) membranes. Blots were blocked in a Tris buffer saline/ 0.1% Tween 20 (TBS-T)

plus 5% dried milk, for one hour at 25°C, rinsed three times in TBS-T, then incubated with primary antibody BAX in TBS-T plus 5% BSA overnight at 40°C. After three washes, the blot was incubated with a secondary antibody conjugated to horse radish peroxidase for one hour at room temperature. After three washes, the signal was developed using a chemiluminiscent substrate and blots were visualized using a Chemiimager. The blots show up as bands on the Chemiimager. A thicker band means more of the BAX protein was expressed compared to the other cells that may have thinner bands. The band size was quantified by measuring the density of the band versus the density of the control.

Statistical Analysis

The statistical analysis was carried out for this study by Student's t-test. Significance was determined by using a p-value < 0.05.

Results

Apoptosis

Figure 2 and Table 1 depict the results of the apoptosis assay. Our data showed a significant increase in apoptosis at both 1 µM and 100 µM concentrations of genistein, with and without the presence of estradiol, compared to the control. The 1 µM genistein cells had an average percent apoptosis of 180.3% higher than the control (100%) and the 1 µM genistein plus estradiol cells increased 213.4%. The 100 µM genistein cells showed an average of 311.6% significant increase in apoptosis over the control. The 100 µM genistein plus estradiol cells showed a significant increase of 337.7% over the control. The 100 µM genistein cells showed a significant increase in apoptosis over the 1µM genistein cells. The increase was significant between 1 µM genistein plus estradiol and 100 µM genistein plus estradiol. The difference in apopto-

Table 1

Effects of Genistein plus Estradiol on Apoptosis in MDA-MB-231 cell

Exposure Groups Compared	Increase in Apoptosis Over the Control	Significance (p-value < 0.05)
1 QM Genistein vs. Control	↑ 180.3%	Significant (p = 0.0027)
1 QM Genistein + Estradiol vs. Control	↑ 213.4%	Significant (p = 0.00017)
100 QM Genistein vs. Control	↑ 311.6%	Significant (p = 1.3 x 10 ⁻⁶)
100 QM Genistein + Estradiol vs. Control	↑ 337.7%	Significant (p = 6.4 x 10 ⁻⁷)
1 QM Genistein vs. 100 QM Genistein	↑ 131.3%	Significant (p = 0.00028)
1 QM Genistein + Estradiol vs. 100 QM Genistein + Estradiol	↑ 124.3%	Significant (p = 0.00035)
100 QM Genistein vs. 100 QM Genistein + Estradiol	↑ 26.1%	Not Significant (p = 0.22)

sis between the 100 µM genistein cells and the 100 µM genistein plus estradiol cells was not significant.

Expression of BAX

The Western Blot and immunodetection showed the levels of BAX expression within the cells. The bands for the Western Blot are depicted in Figure 3. The results of the BAX expression are depicted in Fig. 4. The 1 µM genistein treatment showed a significant decrease in the expression of BAX (20%) compared to the control, while the 1 µM genistein plus estradiol showed a significant increase in BAX expression compared to the control (60%) and to the 1 µM genistein (80%). The 100 µM genistein sample increased significantly in expression over the control (70%). The 100 µM genistein plus estradiol sample decreased significantly in expression when compared with the 100 µM genistein sample (70%), while showing an insignificant increase in expression over the control.

Discussion

Our current study found a significant increase in apoptosis when MDA-MB 231 breast cancer cells were exposed to low and high concentrations of genistein. The results also showed a larger increase in apoptosis when genistein exposure was coupled with estradiol exposure.

The Western Blot results showed a BAX increase within the low concentration of genistein plus estradiol treatment group, but a significantly lower expression in the high concentration of genistein plus estradiol treatment group compared to the control. This result indicates that the 1 µM genistein plus estradiol exposure puts cells through apoptosis via the BAX internal signaling pathway. Since this pathway was expressed less in the high concentrations, our results suggest that this treatment group most likely follows a separate internal signaling pathway to induce apoptosis.

Our results agree with another recent study that examined the effect of varying genistein concentrations (0 µM – 20 µM) on apoptosis of MDA-MB 231 cells (2). This study saw a decrease in cell proliferation and an increase in apoptosis with increasing concentrations of genistein. However, that study was carried out only in the presence of genistein, while our study used a double combination of low concentrations of genistein plus estradiol. Ours is the first report we know of to show that low concentrations of genistein plus estradiol induce apoptosis in ERβ positive MDA-MB 231 cells. Our results are especially relevant since women who are on a soy diet or intake soy as hormone replacement therapy have physiological concentrations of genistein in the range of 4–12 µM (5), the range used in this study.

Figure 2

Effect of Genistein plus Estradiol on apoptosis of MDA-MB 231 cells

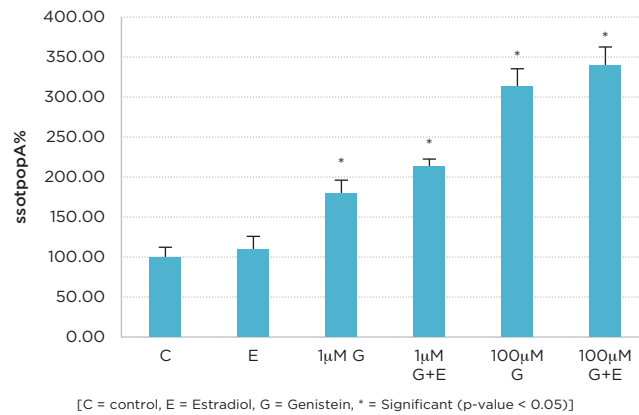


Figure 4

Effect of Genistein Plus Estradiol on the Expression of BAX in MDA-MB 231 Cells

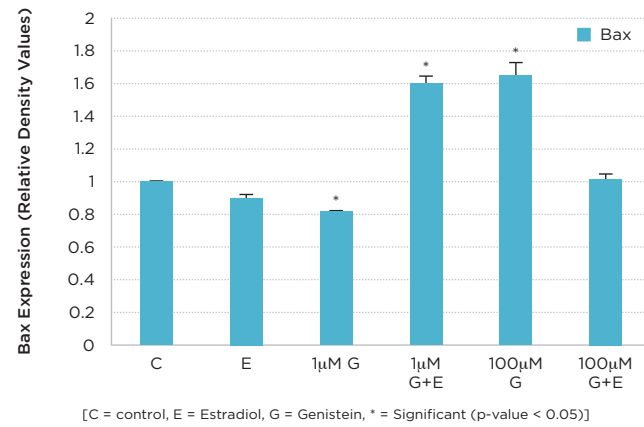


Figure 3

Effect of Genistein Plus Estradiol on the Expression of BAX in MDA-MB 231 Cells



The results of the above-mentioned study also indicated an increase in the expression of BAX with higher concentrations of genistein (2). Our study also showed an increase in BAX expression with higher concentrations of genistein; however upon testing high concentrations of genistein in the presence of estradiol, our study indicated a decrease in BAX expression. This decrease in BAX expression found within the 100 µM genistein plus estradiol cells indicates the possible involvement of a separate cell signaling mechanism.

One pathway that could be involved in the apoptotic behavior of cells is that of caspase protein which leads to apoptosis after BAX is activated (3). The other study indicates an increase in the presence of activated caspase-3, which is responsible for the initiation of apoptosis (2). A possible future study for our lab

could be this alternative pathway to determine if other proteins like caspase-9, which are responsible for activation of caspase-3 (3), show more expression in the presence of high concentrations of genistein plus estradiol. Another study looked at genistein and BAX compared to anti-apoptotic proteins like BCL-2 (6). BCL-2 is a protein that inhibits the cell from entering the apoptotic cycle when activated. The study showed an increase in the pro-apoptotic BAX, while the anti-apoptotic BCL-2 expression decreased (6). A future study can be done to determine if this relationship holds with low and high concentrations of genistein plus estradiol.

This study has shown an increase in apoptosis in MDA-MB 231 breast cancer cells in response to low and high concentrations of genistein exposure with and without the presence of estradiol. Our study is important because, to our knowledge, it is the only study to couple genistein with physiological concentrations of estradiol. The findings are especially relevant in premenopausal women on soy supplementation. They're also important this specific cell line because currently there are no specific treatment protocols for ER-alpha negative, ER-beta positive breast cancer. The ability to recognize not only the end effect of a treatment or molecule on a cancer cell, but also the mechanism through which it responds allows for further studies to determine how to amplify the response better. Understanding the pathways these cells undergo is vital for targeting possible future treatments within the field.

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