Memory’s Rhetoric: Narrating Morality in Augustine and Du Bois

Using Differential Aerodynamic Forces for CubeSat Orbit Control

Gene Expression of Nuclear Receptors and Multidrug Transporters in Canine Lymphoma and Mammary Tumor Cells

Construction and Testing of a ColTRIMS Apparatus for Pair Production by Electron Impact
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About the Editors

**Patrick Donnan** is a senior pursuing dual degrees in Physics (B.S.) and Music (B.A.) with a minor in Mathematics. His research interests are in theoretical atomic, molecular and optical (AMO) physics, which he has researched for the past three years under Prof. Francis Robicheaux. He is author or co-author on six journal articles, including two in AUJUS, and has presented his work at numerous conferences. Among other honors, he is a Goldwater Scholar, a two-time Undergraduate Research Fellow and a recipient of the national Society of Physics Students Outstanding Student Award for Undergraduate Research. He aims to pursue a doctorate in theoretical AMO physics after graduation.

**Paige Lenssen** is a senior pursuing a Bachelor of Science in Business Administration (Finance) and a Bachelor of Arts in English (Professional Writing and Literacy Studies) with a minor in French. Apart from her involvement with AUJUS, she is a drum major for the Auburn University Marching Band and a student assistant for the College of Business. She has formerly served as president of Women in Business and as tenor saxophone section leader for the AU Marching Band. She has been awarded Mortar Board’s Mildred Enloe Yates Award as well as the Mary Matherly Durant Award for her character and achievement in the English Department. Paige is a member of Phi Kappa Phi honor society and the Honors College, and she plans on pursuing a career in financial services or technical writing.

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As we celebrate the third issue of the *Auburn University Journal of Undergraduate Scholarship*, we feel ever more strongly the important role of publication in research training. Professional publication signifies the culmination of a systematic investigation or creative inquiry, the process and results of which have been reviewed by a group of experts. Without this endorsement from a community of scholars, we have no valid means of judging the significance of the research contribution. Conveying the critical role of refereed publications is fundamental in preparing students for professional careers.

We are proud to offer Auburn students and faculty a chance to publish undergraduate research. Such a vehicle would not be possible without the combined efforts of many dedicated individuals: the faculty mentors who guide undergraduates through the research process, the experts who review the submissions, the student authors who understand the importance of sharing research results with a broad audience, and the student editors and production staff who make it all come together.

This year’s issue represents only a snapshot of the undergraduate research taking place on Auburn’s campus. We hope you will join us in congratulating the student authors and their mentors for their scholarly accomplishments and in encouraging other students from all disciplines to submit their original work for next year’s issue. We urge any students interested in joining the editorial team to contact us and get involved.

Lorraine W. Wolf
Director of Undergraduate Research
Professor of Geophysics

Margaret J. Marshall
Director of University Writing
Professor of English
When I ask Dr. Biaz about the research he’s conducted with undergraduate students, it’s immediately apparent that he loves what he does: his eyes light up as he describes his work with UAVs.

“UAVs: Unmanned Aerial Vehicles,” he explains. “Would you like me to show them to you?” After a short walk, we’re standing in a Shelby laboratory filled with what appear to be styrofoam airplanes, each about two feet in length.

“We went with the idea of flying UAVs in a limited space without them hitting each other,” he explains. “Most people, when they fly UAVs, they’re looking at only trying to fly one or, at most, two [...] but, in fact, we achieved our goal of flying up to 16 UAVs in 1 km².” Reaching this aim reflects the high caliber of Dr. Biaz’s undergraduate students—the average GPA in his team is 3.84.

“It’s very selective,” he admits. “This summer I am expecting at least 250 applicants. [...] We’ll accept, this time, ten.” Many of these top-tier applicants have worked at elite institutions, and Dr. Biaz is thrilled that they want to participate in research at Auburn. Even the ones who aren’t accepted, he says, “are going to Berkeley; they are going to MIT; they are going to Princeton... and they are saying, ‘I wish I could have done [research] with you.’”

Dr. Biaz attributes the success of his research program largely to his undergraduate students. “Ninety-five percent of the work in the last four years was [done] by undergrad students,” he says. I ask if their contributions make a real impact in the computer science field. “Yes! Especially with UAVs,” he replies emphatically.

Because flying multiple UAVs at once is so difficult, Dr. Biaz’s students have designed an innovative simulation system where one real UAV is flown in conjunction with many simulated UAVs. “In the air, you see real UAVs that are flying, but they are trying to avoid fake [UAVs] that are just on the computer. And the fake ones, they avoid the fake ones and the real ones,” Dr. Biaz explains. This allows the team to experiment with flying many vehicles in a small airspace with fewer crashes and complications.

But what happens when things do go awry?

“This is our cemetery.” Dr. Biaz grins and points to a large trashcan overflowing with broken planes. “We have our share of failures. [...] Many students approach me and say, ‘I crashed this’ or ‘I did that.’ What is important is that you say, ‘That’s normal.’ Because imagine if [...] you had only successes. That would be boring!”

His students appreciate this supportive outlook. “Dr. Biaz was always very encouraging when we ran into problems,” says Victoria Wu, one of Dr. Biaz’s former research students. “[He] was overall an incredibly positive mentor.”
Dr. Biaz thinks that obstacles offer students the chance to develop their skills.

“Failure is a part of the game,” he says. “And in some sense, that is the teaching moment for you to say, ‘That’s okay! Don’t worry about it; try to find the source of your mistake.’”

So what advice does Dr. Biaz have for students who want to do research?

“They have to get interested in some question that they have.” He says students need that “I want to do it” attitude. I ask him about the source of his own motivation. “It was my son. My son told me, ‘Dad, what you do is boring,’” Dr. Biaz says with a laugh. “[So] I thought about when I was a kid… I was 8, and really I was dreaming of having a UAV that I could send wherever I want. […] I said, ‘Let me do that—what kids dream.’ And I did.”

He assures me that doing research with undergraduates benefits all parties involved. “I’m getting a lot from those undergraduate students,” he says. “They are helping my career. We are producing papers. This helps me and it helps them also.” As for the students, Dr. Biaz says that, upon graduating, many of them go “to very, very good companies like Apple, Google, Cisco.. all those big names” while others “become faculty elsewhere.”

“Dr. Biaz took personal interest in each of the students,” says Christopher Hudson, a student who worked on the UAV program with Dr. Biaz over the summer. “I was very fortunate to have been mentored by him.” “Dr. Biaz […] helped me to see just how fun and rewarding research can be,” Wu adds.

And the final sentiment offered to me as I leave? Never stop learning.

“By the way, I am also an undergraduate student at Auburn,” he says happily. Dr. Biaz is a professor with a bachelor’s degree, a master’s degree, and two Ph.D.s, and yet he still feels there is so much to learn. I ask about his major, and can’t help but smile at his answer.

“I am… what is that name that they give? I’m ‘undecided.’”
Memory’s Rhetoric: Narrating Morality in Augustine and Du Bois

Gabby Bates

Abstract
This article explores how St. Augustine and W. E. B. Du Bois, while writing within different cultural contexts and for different purposes, both employ personal narrative as a rhetorical strategy to search for and relay what they consider to be essential truths. In a style that mirrors the modern conception of memoir, a subgenre of creative nonfiction, both men recreate their own personal experiences and then interpret those experiences in light of larger human realities. They offer themselves up as character archetypes, employing narration to model self-examination. This article unpacks specific utilizations of creative nonfiction elements in two works—St. Augustine’s Confessions and Du Bois’ “A Negro Schoolmaster in the New South”—to argue that such strategies contribute to strong authorial credibility, emotional investment of the reader via imaginative participation, and a less abrasive, more inviting central argument. This article goes beyond an analysis of how these two works can be read and interpreted as works of memoir; it argues that the creative nonfiction strategies also mirror, structurally, the long-standing role of memory in shaping spiritual and secular human philosophies, both at the individual and societal levels.

Introduction
Memory—we are all aware of its faultiness, of how easily it falls prey to the corrosion of time and the dusty compartments of our psychologies. And yet, when in search of spiritual, philosophical, and societal truths, we rely on memory as a platform from which to dive into our own individual welters of experience. Like St. Augustine in Confessions and W. E. B. Du Bois in “A Negro Schoolmaster in the New South,” we tap into our recollections and then analyze the meaning and consequences of our experiences through the lens of hindsight. Perhaps we learn valuable lessons that will allow us to bolster our integrities and live more fulfilling lives. Often, however, we do not stop there; we go on to draw widespread conclusions from personal experiences and argue for their relevance at the universal level. In this way, memory and narrative nonfiction serve as a form of education, both for the self and others.

The connection between St. Augustine and W. E. B. Du Bois may not be obvious, but their moralities converge early in American history, mingling in the intellectual bedrock of Puritan New England. In his magisterial history of Puritan New England’s early days, Perry Miller begins with a chapter of “the Augustinian Strain of Piety,” in which he draws parallels between St. Augustine’s self-examination in Confessions and the introspective writing employed by the Puritans (1954, p. 3). These Puritans went on to establish many of America’s most noteworthy educational institutions, among them Harvard College, where W. E. B. Du Bois later became the first African American to receive a doctorate in 1890 (Kimball, 2009, p. 5). Thus, Du Bois the moralist is directly engaged with the intellectual legacy of Puritan New England, a
memory and literary self-examination. I am grateful to an anonymous reviewer for bringing my attention to this Puritan connection between St. Augustine and Du Bois. Unfortunately, time and space did not allow for a deeper look into these intersections. The topic certainly merits exploration in a subsequent essay.

St. Augustine, whose impact on the early Christian church would be hard to overstate, exhibits the rhetorical process of personal narration to make various arguments about how humans learn and how humans should live. In his essay “A Negro Schoolmaster in the New South,” W. E. B. Du Bois tells a story from his own life in order to make an argument about formal education and expose its failure to combat severely ingrained racial inequalities. The text of “A Negro Schoolmaster in the New South” lives on in slightly altered form as Chapter 4 of the 1903 edition of The Souls of Black Folk, a collection heralded for its groundbreaking critiques of racism and the reconstruction of African American identity (Walker, 2004). While St. Augustine’s primary focus is spiritual and Du Bois’ is purposefully secular—Du Bois avoids identification with white Christian ideology due to its association with slavery (Kahn, 2004, p. 18)—both authors employ personal memory and creative nonfiction narration to draw universal conclusions and make an argument for particular beliefs about education. The convergence of St. Augustine and W. E. B. Du Bois’ moralities in early Puritan England, as well as the power and endurance of their individual legacies in American consciousness, speaks to the rhetorical success of these creative nonfiction strategies.

Structure and Meaning

The structural progression of St. Augustine’s Confessions is primarily chronological. However, St. Augustine frequently shifts from the recreation of past events to an interpretation of those events from his perspective as an adult. As he recounts experiences from childhood, coming-of-age, early adulthood, and so on in a chronological progression, he employs a double vantage point to weave interpretation and critical self-reflection into the scenes. In this way, the overarching structure of Confessions simultaneously maps out St. Augustine’s life and speaks to the interconnectedness between past and present. This idea that our past selves hold important lessons for our present identities is at the heart of St. Augustine’s literary exploration.

Similarly, the structural strategies employed by Du Bois in “A Negro Schoolmaster in the New South” play a role in its enduring success. In the essay, Du Bois presents a personal experience in first person narration to get at a larger truth about formal education in the context of the Jim Crow South. Marshall asserts that Du Bois merges narrative features with analytical ones to blur genre lines (1995, p. 121); I would argue that we can call this blurred genre “creative nonfiction,” and that by employing it, Du Bois is able to effectively convey more complex meanings. The structure of the essay is similar to the structure of Augustine’s Confessions. First, the focus is on a recreation of events, and then the focus shifts to interpretation and commentary. Du Bois’ essay is structured by significant journeys and transitions in his own life, and the narrator progresses in years, knowledge, and experience as the essay unfolds. The physical act of returning, which Du Bois performs within the narrative by traveling back to the rural Tennessee community where he taught for two summers as a younger man, mirrors the mental return of the personal narrative form in that the speaker is looking back to make sense of certain events to arrive at a larger cultural truth.

Memory: Personal and Collective

In Confessions, St. Augustine explores the role of recollection in the procurement of truth. Examples include when he tells God, “The memory is bitter, but it will help me to savour your sweetness” (2009, p. 470) and when he says, “Allow me, I beseech you, to trace again in memory my past deviations and to offer you a sacrifice of joy” (2009, p. 477). In these prayerful addresses, St. Augustine conveys the interconnectedness of memory, truth, and fulfillment. Subsequently, he argues for the process of recollection and analysis of motive as a way for all individuals to reach more mature spiritual states and live more meaningful lives.

It is pertinent to note that St. Augustine does not limit the notion of memory to personal powers of
recollection. In fact, in the absence of personal memory, St. Augustine excavates meaning from the memories of his family and loved ones. He also employs observation, specifically the observation of babies, as a form of memory; because he cannot recall his own infancy, this observation gives him insight into how he must have experienced the world at the same age (2009, p. 464). St. Augustine overtly claims that men can discover truths about themselves by observing others and listening to the tales of the women, a claim that lends credence to St. Augustine’s overarching exercise in Confessions (2009, p. 464). By characterizing memory as a collective entity, rather than a purely solitary exercise, St. Augustine primes readers to engage in the spiritual discourse themselves. He invites readers to participate in a similar exercise by using his memories as a resource to help them discover the meaning of their own lives.

Du Bois’s “A Negro Schoolmaster in the New South” was published in Atlantic Monthly in 1899, after attempts had been made to formally educate former slaves, but before a public school system had become widespread (Caruthers & Davis, 2006, p. 81). In this cultural context, literacy was viewed by many former slaves to be a condition necessary for freedom (Caruthers & Davis, 2006, p. 79). An important question at this time, however, and one addressed by Du Bois in his essay, was whether or not education could actually be a key to freedom or if it would become yet another agent of racial oppression (Marshall, 1995, p. 119). Du Bois does not offer an answer to this central question in “A Negro Schoolmaster in the New South.” Rather, he engages directly with the question himself, participating in the debate that plagues many other African Americans of his time. Therefore, while Du Bois does not explicitly state the function of collective memory in his piece, readers informed of the work’s cultural context see that the collective memory of slavery influences the thoughts of the speaker and the story he decides to tell.

Image and Scene

Poet William Blake famously wrote, “To see a World in a Grain of Sand/ And a Heaven in a Wild Flower” (1950, pp. 1-2). The idea expressed in these lines, that abstractions should be rooted in concrete details, breathes life into all great literature, regardless of genre. In other words, implicit in creative nonfiction, as in all forms of creative writing, is the notion that the inclusion of physical particulars allow for deeper knowledge of intangibles, such as feelings of shame or sadness. Physical particulars are also the building blocks of image and scene. Therefore, to understand how Confessions and “A Negro Schoolmaster in the New South” achieve effective argumentation through creative nonfiction strategies, close attention must be paid to the function of image and scene in both works.

The pear theft constitutes one of Confessions’ most powerful scenes. Its narrative form allows St. Augustine to present himself as an example and his specific experiences as a sort of universal parable. Furthermore, the image of the pear tree “loaded with ugly fruit” gives the reader a more rounded understanding of the frustrated shame that St. Augustine feels when he tries to understand why he stole them (2009, p. 472). By pairing the pears—something we can feel, see, and taste in our imaginations—with the heavy spiritual abstractions of sin and shame, St. Augustine achieves visceral reader engagement and a stronger argument.

St. Augustine’s focus on the personal and the particular in this scene has thematic implications. The contrast between the petty act of mischief he commits as a young man and the severe sense of remorse that St. Augustine suffers over it later in life provides evidence to support his overarching argument that any sinful act, no matter how small, can have long-lasting spiritual effects. While excavating shameful motives can be painful, he argues, it enables spiritual growth; therefore, it is a valuable exercise in which his readers should similarly engage. Rather than state this objective explicitly, he employs a concise narrative to show his meaning visually and engage his readers in the meaning-making process.

Du Bois employs image-rich details in a similar way to engage readers and bolster his ethos. Specifically, his physical descriptions of people and places infuse his essay with a real-life quality that both encourages audience investment and enhances the reliability of Du Bois’ interpretations. If he can create a believable world populated by believable people, he can speak from a position
of more credible authority. For example, Josie, one of the most important characters in the piece, is introduced as being "dark skinned" and "homely," with an anxious desire for education and a passionate longing to learn (Du Bois, 1899, p. 2). With her academic determination and timid, likable disposition, she comes to represent goodness and innocence. Du Bois’ ultimate argument for a re-evaluation of education as power is strengthened by the inability of precious Josie to overcome the oppression of her cultural context.

Thwarted and ultimately killed by Jim Crow oppression and poverty, Josie exhibits the failure of public schools to combat racial oppression and instills a sense of injustice in the reader. Near the end of “A Negro Schoolmaster,” Du Bois asks, “How shall man measure Progress there where the dark-faced Josie lies?” (1899, p. 7). He uses his memory of Josie, her specific image, and the story of her sad, short life to try and glean a larger understanding about his society and how his fellow human beings should perceive the world around them. The way visual memory functions as a springboard into cultural analysis in this instance is reminiscent of how St. Augustine’s pear theft memory serves as an entry point into spiritual analysis.

**Limitations of Formal Education**

Some of St. Augustine’s later narratives contain arguments about rhetoric and the role of formal rhetorical education. By recalling his own experiences with formal rhetorical education, St. Augustine makes arguments for what rhetoric is and what it should be. St. Augustine takes the personal and makes it universal in such statements as, “The more unscrupulous I was, the greater my reputation was likely to be, for men are so blind that they take pride in their blindness” (2009, p. 475). In this statement, St. Augustine makes a negative argument about rhetoric, as well as human nature, by taking the memory of his own personal experience and connecting it to a larger human truth in a single sentence. The argument, that rhetoric as a secular form is rooted in vanity, is lent credence by Augustine’s experience and his analysis of that experience as part of a universal human affliction of sin.

When St. Augustine looks back over his experience in formal rhetoric education, he defines rhetoric as a sinful art. In this segment, St. Augustine refers to rhetoric as “the art of eloquence” and claims that his initial study of the art was driven by an “ambition to be a good speaker” for no other reason than to gratify vanity (2009, p. 475). Employing personal memory, he paints an unfavorable picture of his rhetorical studies, describing the art as “unhallowed,” “inane,” and selfish (2009, p. 475). Later, when describing his experience as a teacher of rhetoric, St. Augustine furthers his negative definition of the art. He makes a universal argument about the motives behind secular rhetoric education by presenting statements of personal confession. For example, he admits that he taught from a “love of money” and that he “taught the tricks of pleading” (2009, p. 478). The implied argument within these personal statements is that formal rhetorical education is rooted in conceit and unfulfilling trickery.

St. Augustine relays several other personal narratives to reveal the uselessness of secular rhetorical study. For example, after looking back over his experience of reading Aristotle’s highly revered book about the “Ten Categories” at Carthage, St. Augustine says, “What profit did this study bring me? Nothing” (2009, p. 481). In fact, he claims that the study actually did him harm in that it encouraged him to think narrow-mindedly about philosophical concepts. By calling attention to the contrast between what he perceived in his twenties as being important and worthwhile and what he now knows is important and worthwhile, St. Augustine presents a universal argument through a double vantage point, not just about rhetoric,
but about life itself; he argues that all actions are useless that do not pursue the discovery of a larger truth, namely a fuller understanding of God. In this instance, not only did the study of rhetoric fail to lead St. Augustine to a larger truth, it actually hindered him from doing so. Double vantage point, as employed here by St. Augustine, is a strategy at the heart of many of today’s literary memoirs, and this perspective provides a convincing argument for St. Augustine’s position on formal rhetorical study.

While St. Augustine often uses his recollections to paint a negative picture of secular rhetoric education, his accounts do not claim that the formal education process is entirely meritless. In fact, according to his narratives, a major turning point in his spiritual journey occurred when he was assigned readings by Cicero. The philosophical study Cicero encouraged led St. Augustine to hunger for deeper, eternal truths. In praising Cicero’s influence in his life, St. Augustine says, “It was not the style of it but the contents which won me over” (2009, p. 475). This statement relies on personal memory to make an argument about rhetoric: content is more powerful and more important than eloquence. Also, he asserts that rhetoric can be a worthy pursuit as long as it is inspired by a deeper truth and not simply a desire to successfully dominate an opponent.

In regards to formal education, Du Bois—like St. Augustine—lends reserved credence to Cicero’s classic rhetorical instruction. When parents of his students started doubting formal education and stopped sending their kids to school, Du Bois says, “I put Cicero pro Archia Poeta into the simplest English with local applications, and usually convinced them—for a week or so” (1899, p. 4). This statement both praises classical rhetoric and calls attention to its limitations. Du Bois shows that while Cicero’s texts can still be employed in the modern-day, the strategies are only temporarily effective. Unlike St. Augustine, Du Bois does not attempt to unearth the sinful underpinnings of formal rhetoric, but he does mention its limitations to fortify his argument that formal education is not enough to combat the engrained oppression and cycle of poverty in the New South. Perhaps, the ironic voice of the speaker asks in this sentence, education is not the solution to our social problems after all. Even with his formal education, Du Bois is unable to convince parents to fight racial oppression by keeping their children in school.

Unlike St. Augustine, Du Bois does not come to a resolute conclusion about the role of formal education at the end of his story. He presents the personal narrative, fleshes out characters and settings, wonders as to the meaning behind the memories, and then leaves the reader with a sense of troubled angst. This ending is effective because his argument is not for a specific course of action, but for a re-evaluation. By ending the narrative with the sentence, “Thus sadly musing, I rode to Nashville in the Jim Crow car,” Du Bois stresses the failure of formal education to combat the forces of entrenched racial stratification and argues for an immediate re-evaluation of this issue (1899, p. 7). He has received the highest formal education available, and yet he is still not treated as an equal. The dissatisfaction and sadness he feels at the end mirrors the dissatisfaction and sadness the reader feels after vicariously experiencing Du Bois’ journey. This emotional component strengthens the argument about formal education because it leaves the reader with the sense that a serious issue is unresolved and something needs to be done.

In light of the enduring poverty and lack of educational equality in the African American community, the main argument in Du Bois’ narrative essay remains relevant to this day. Racism, although outlawed, has not disappeared; it has simply started speaking more softly, treading with lighter step through American hallways. Having integrated our schools and failed to achieve racial
equality, we are still left with the question that plagues Du Bois in “A Negro Schoolmaster in the New South”: if education is not the path to racial equality, what is? The enduring legacy of the issues critiqued by Du Bois in his essay could be seen as evidence that the piece is ineffective, but I would argue it is more a testament to how large a social injustice he is attempting to combat. Du Bois writes toward ambitious goals, employing creative nonfiction narration as a rhetorical vehicle in the hopes of achieving them.

**Conclusion**

Long before the contemporary memoir craze, St. Augustine and W. E. B. Du Bois produced memory-based works that shaped human philosophies. They write in different cultural contexts and for different purposes, but both authors employ creative nonfiction as a rhetorical strategy to search for and relay what they consider to be essential truths regarding education. They recreate personal experiences and then interpret those experiences in light of larger human realities, offering themselves up as archetypes for particular practices and beliefs. The result of the creative nonfiction strategies in these works is strong authorial credibility, emotional investment via imaginative participation, and central arguments that compel readers toward similar introspective explorations and conclusions to this day.

**References**


Gene Expression of Nuclear Receptors and Multidrug Transporters in Canine Lymphoma and Mammary Tumor Cells

Kodye L. Abbott, Elaine S. Coleman, Bruce F. Smith, Richard C. Bird, Annette N. Smith, Mansour Mahmoud, Pondugula R. Satyanarayana

Abstract

Chemoresistance is a major barrier to successful chemotherapy in canine lymphomas and mammary tumors. Several mechanisms have been shown to contribute to chemoresistance in a variety of cancers. One such mechanism is the overexpression of drug efflux pumps, called multidrug transporters, that result in reduced efficacy of chemotherapy drugs and thereby lead to chemoresistance. Nuclear receptors play a major role in regulating the gene expression of these multidrug transporters. However, the expression profile of multidrug transporters and nuclear receptors is largely unknown in canine lymphoma and mammary tumor cells. The goal of this study was to determine gene expression of multidrug transporters and nuclear receptors in canine lymphoma and mammary tumor cells. We examined the expression of the pregnane xenobiotic receptor, constitutive androstane receptor, aryl hydrocarbon receptor, peroxisome proliferator-activated receptor, multidrug resistance protein 1, and multidrug resistance-associated proteins using RT-PCR with gene-specific primers on total RNA isolated from canine lymphoma and mammary tumor cells. RT-PCR results show that the nuclear receptors and multidrug transporters are differentially expressed in the canine cancer cells and may in part explain a mechanism for differential chemoresistance in canine cancer patients. This is the first study to broadly investigate gene expression of multidrug transporters and their corresponding nuclear receptors, which are transcription factors, in canine lymphoma and mammary tumor cells.

Introduction

Chemotherapy is commonly employed for treating canine lymphoma and mammary tumors. However, routinely used chemotherapy drugs lose their therapeutic efficacy during the later stages of treatment due to development of chemoresistance, resulting in relapse and poor clinical outcome. Multiple mechanisms may contribute to chemoresistance. In a variety of cancers, chemoresistance is associated with overexpression of multidrug transporters, such as multidrug resistance protein 1 (MDR1) and multidrug resistance-associated proteins (MRPs) (Pondugula & Mani, 2013; Borst, Evers, Kool, & Wijnholds, 2000; Marzac et al., 2011; Chen, 2010). Functionally, these transporters prevent the retention of cytotoxic drugs within tumor cells resulting in little or no cytotoxic effect. For example, MDR1, MRP1, MRP2 and MRP3 can preclude the cytotoxic effect of classical chemotherapeutics, vincristine and doxorubicin, by exporting them from tumor cells (Borst et al., 2000; Sharom, 2008; Sodani, Patel; Kathawala, & Chen, 2012; Okamura, Sakaeda, & Okumura, 2004).

Chemoresistance in canine lymphoma has been shown to be associated with upregulation (i.e., an increase in expression and/or function) of MDR1 (Fan, 2008; Lee, Hughes, Fine, & Page, 1996; Moore, Leveille, Reimann, Shu, & Arias, 1995; Steingold et al., 1998). Expression of MDR1 in malignant lymphocytes at relapse was significantly higher than that found before the initiation of chemotherapy (Fan, 2008; Lee et al., 1996; Moore et al., 1995; Steingold et al., 1998; Uozurmi, Nakaichi, Yamamoto, Une, & Taura 2005). Similarly,
Gene expression of multidrug transporters is activated mainly by certain ligand-dependent nuclear receptors. These receptors include pregnane xenobiotic receptor (PXR), constitutive androstane receptor (CAR), aryl hydrocarbon receptor (AHR), peroxisome proliferator-activated receptor alpha (PPARα) and PPARγ (Pondugula & Mani, 2013; Chen et al., 2012; Klaassen, & Slitt, 2005; Konieczna, Lichnovka, Erdosova, & Ehrmann, 2009; Cizkova, Konieczna, Erdosova, Lichnovska, & Ehrmann, 2012; Maher et al., 2008; To, Yu, Liu, Fu, & Cho, 2012; Moffit et al., 2006). It has been reported in many cancers that chemoresistance is associated with upregulation of nuclear receptors, and of multidrug transporters, namely MDR1 and MRPs (Pondugula & Mani, 2013; Chen et al., 2012). It is possible that some of these nuclear receptors and multidrug transporters are overexpressed in canine lymphomas and mammary tumors. However, a broad expression profile of the nuclear receptors and the multidrug transporters has yet to be determined. In the current study, we investigated gene expression profiles of the nuclear receptors and multidrug transporters in canine lymphoma and mammary tumor cells using RT-PCR.

Materials and Methods

Cell culture

Canine OSW T-cell and GL-1 and 17-71 B-cell lymphoid cell lines were grown in RPMI-1640 medium (Lonza), which was supplemented with 10% fetal bovine serum (HyClone, Logan, UT), 100 U/ml penicillin and 100 µg/ml streptomycin (Cellgro, Manassas, VA), 2 mM L-glutamine (Cellgro), and 1 mM sodium pyruvate (Cellgro). Canine mammary tumor cells (CMT12, CMT27 and CMT28) were grown in DMEM, which was supplemented with the same additives. The cells were cultured in an incubator with a humidified atmosphere maintained at 5% CO₂ and 95% air at 37°C. These cell lines are known to reflect in vivo properties and widely used for lymphoma and mammary tumor studies (Uozurmi et al. 2005; Jamadar-Shroff, Papich, & Suter, 2009; Kisséberth et al., 2007; Kojima, Fujino, Goto-Koshino, Ohno, & Tsujimoto, 2013; Matsuda et al., 2010; DeInnocentes, Agarwal, & Bird, 2009).

RNA isolation and quantitation

Total RNA was extracted from the lymphoid and mammary tumor cells by using the RNeasy Mini Kit (Qiagen; Valencia, CA). The quality and quantity of the total RNA were determined using NanoVue Plus Spectrophotometer (GE Healthcare). Dog liver total RNA was provided by Dr. Bruce Smith.

RT-PCR analysis

Reverse transcription was performed with the QuantiTect Reverse Transcription Kit (Qiagen) to synthesize cDNA from total RNA following the manufacturer’s protocol. PCR was performed on cDNA using gene specific primers (Table 1), Taq PCR Master Mix Kit (Qiagen) and iCycler (Bio-Rad; Hercules, CA) according to the manufacturer’s protocol. Each of the 40 PCR cycles consisted of the following steps: 94°C for 1 minute, 55°C for 1 minute, and 72°C for 1 minute.

RT-PCR optimization

RT-PCR was performed on dog liver total RNA to optimize the specificity of gene specific primers (Table 1). PCR products were electrophoresed on 2% agarose gels and detected by ethidium bromide (Figures 1, 2 & 3). The PCR products were then purified using the gel extraction kit (Qiagen) and sequenced to verify their identities. Sequences were verified using PubMed BLAST search.

Results

Gene expression of nuclear receptors

While the transcript for pregnane xenobiotic receptor (PXR) was detected only in OSW and 17-71 cells (Table 2), aryl hydrocarbon receptor (AHR) was found to be expressed in all the cell lines tested except OSW (Table 2). Constitutive androstane receptor (CAR) was found to be expressed in all cell lines excluding OSW and GL-1 (Table 2). Finally, peroxisome proliferator-activated receptor alpha (PPARα) and (PPARγ) were detected in all the cell lines except GL-1 (Table 2).

Gene expression of multidrug transporters

The transcript for MDR1, MRPI, MRPS, MRPD and MRP7 was found to be expressed in all the cancer cell lines (Table 3). MRP2 was not detected in OSW, and MRP8 was not detected in GL-1 and CMT12.
Table 1. Primers for RT-PCR analysis

<table>
<thead>
<tr>
<th>Gene</th>
<th>Primer Direction</th>
<th>Sequence (5’ – 3’)</th>
<th>GeneBank Accession Number</th>
<th>Amplicon size (base pairs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHR</td>
<td>Right</td>
<td>AGCCCATTAGCGTCATCAAC</td>
<td>XM_532485.3</td>
<td>329</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>GCATTACAGTCCTCCCAAC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAR</td>
<td>Right</td>
<td>TTCGCTGGAAGCTGTAAGGT</td>
<td>FJ202015.1</td>
<td>244</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>AGGCCTGAAXACTGCAAAACT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PXR</td>
<td>Right</td>
<td>GTCAGGAGGATCTGTCGTC</td>
<td>AF454670.1</td>
<td>198</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>CAATTCCTGAAATTGGAGAA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPARa</td>
<td>Right</td>
<td>TCTTCTCAGCCATGCACAAAC</td>
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<td>215</td>
</tr>
<tr>
<td></td>
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<td>AGCAAAACTGAAAGCGGAAA</td>
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<td>PPARy</td>
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<tr>
<td></td>
<td>Left</td>
<td>TGAGAAGCCCTTTGGTGAC</td>
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<td></td>
</tr>
<tr>
<td>MDR1</td>
<td>Right</td>
<td>TGGAGACATCCTGCTGAGC</td>
<td>FJ617477.1</td>
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<tr>
<td></td>
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<td>CCACTGGAGAGGAAATGA</td>
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<td></td>
</tr>
<tr>
<td>MRP1</td>
<td>Right</td>
<td>GCTCCTTCTGTTGGGTCTTA</td>
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<td>293</td>
</tr>
<tr>
<td></td>
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<td>CAGTGCCTCTTCTTTCTCCA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRP2</td>
<td>Right</td>
<td>AAGTCTGTTAGGAGGGCACA</td>
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<tr>
<td></td>
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<td>GCACGTGAGGCTCTGGAAG</td>
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<td>MRP3</td>
<td>Right</td>
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<tr>
<td></td>
<td>Left</td>
<td>CATCCTGAGCATCTACTTCC</td>
<td></td>
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</tr>
<tr>
<td>MRP4</td>
<td>Right</td>
<td>GAGGGGAGAAGAGGAGGTGC</td>
<td>NM_001197174.1</td>
<td>250</td>
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<td></td>
<td>Left</td>
<td>TGATGCGTGGGAAAAGTCC</td>
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<tr>
<td>MRP5</td>
<td>Right</td>
<td>ACAAGCCAATCCGTAACTGC</td>
<td>NM_001128100.1</td>
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<tr>
<td></td>
<td>Left</td>
<td>CAGAGACCCTCCGAGGAAGC</td>
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</tr>
<tr>
<td>MRP6</td>
<td>Right</td>
<td>AAGAAATCTGAGGAGGAGGAG</td>
<td>XM_547113.4</td>
<td>292</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>GTTGAGACGACACTACATG</td>
<td></td>
<td></td>
</tr>
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</tr>
<tr>
<td></td>
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<td>CTGTCTGGGTCTCAGTCTCT</td>
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<td></td>
</tr>
<tr>
<td>MRP8</td>
<td>Right</td>
<td>CACCATCAAGAGCACGGGCA</td>
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<tr>
<td></td>
<td>Left</td>
<td>GGACAAATAGCAGCAGAAGAG</td>
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<td></td>
</tr>
<tr>
<td>MRP9</td>
<td>Right</td>
<td>TCCCCAATCTCAGTCAGTC</td>
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<td>80</td>
</tr>
<tr>
<td></td>
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<td>CCCAGAGGACAAAGTGCTA</td>
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</table>

Interestingly, MRP6 was detected only in the mammary tumor cells (Table 3). MRP5 and MRP 9 were present in liver, but have yet to be tested in the lymphoma and mammary tumor cells (Figure 3 and Table 3).

**Discussion**

Chemoresistance is a major cause of chemotherapy failure in dogs with lymphoma and mammary tumors. While upregulation of certain nuclear receptors and multidrug transporters has been shown to contribute to chemoresistance in several human cancers (Pondugula & Mani, 2013; Chen et al., 2012), an expression profile of these receptors and transporters is poorly understood in canine lymphoma and mammary tumor cells. Our study determined that certain nuclear receptors and multidrug transporters are differentially expressed in multiple canine lymphoma and mammary tumor cells. The degree of response to chemotherapy greatly varies in dogs with lymphoma or mammary tumors. The cell lines used in this study were derived from different canine cancer patients that possibly had a variable response to chemotherapy. Therefore, the differential expression profile of nuclear receptors and multidrug transporters may in part explain how a given chemotherapy treatment can have a varying impact depending on the type of canine cancer.
Figure 1. RT-PCR of MDR1 and PXR under optimized conditions. RT-PCR was performed on dog liver total RNA to optimize an RT-PCR for each gene (data shown for PXR and MDR1). A single and specific band was observed at the expected size for cDNA templates. No signal was observed in RNA template (RNA) or in no template (H₂O) controls. Identity of the bands was verified by sequence analysis. M, 100-bp ladder; PXR, Pregnane xenobiotic receptor; and MDR, multidrug resistance protein.

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>RNA</th>
<th>H₂O</th>
<th>cDNA</th>
<th>M</th>
<th>RNA</th>
<th>H₂O</th>
<th>cDNA</th>
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</thead>
<tbody>
<tr>
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<td>H₂O</td>
<td>cDNA</td>
<td>M</td>
<td>RNA</td>
<td>H₂O</td>
<td>cDNA</td>
</tr>
<tr>
<td>PXR</td>
<td>P</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>P</td>
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Figure 2. RT-PCR for gene expression of nuclear receptors in dog liver under optimized conditions. Single band was observed at the expected size. Identity of the bands was verified by sequence analysis. M, 100-bp ladder; AHR, aryl hydrocarbon receptor; CAR, constitutive androstane receptor; PPAR, peroxisome proliferator-activated receptor; and PXR, pregnane xenobiotic receptor.

Table 2. Analysis of gene expression of nuclear receptors in canine lymphoma (OSW, 17-71 and GL-1) and canine mammary tumor (CMT27, CMT28 and CMT12) cells. P, present; ND, not detected; PXR, pregnane xenobiotic receptor; AHR, aryl hydrocarbon receptor; CAR, constitutive androstane receptor; and PPAR, peroxisome proliferator activated receptor.

<table>
<thead>
<tr>
<th></th>
<th>PXR</th>
<th>AHR</th>
<th>CAR</th>
<th>PPARα</th>
<th>PPARγ</th>
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<td>ND</td>
<td>ND</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>17-71</td>
<td>P</td>
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<td>P</td>
<td>P</td>
</tr>
<tr>
<td>GL-1</td>
<td>ND</td>
<td>P</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
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<tr>
<td>CMT27</td>
<td>ND</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>CMT28</td>
<td>ND</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>CMT12</td>
<td>ND</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
</tbody>
</table>
The nuclear receptors PXR, CAR, AHR, PPARα and PPARγ, are known to activate gene expression of multidrug transporters (Pondugula & Mani, 2013; Chen et al., 2012; Klaassen, & Slitt, 2005; Konieczna et al., 2009; Gzikova et al., 2012; Maher et al., 2008; To et al., 2012; Moffit et al., 2006). Overexpression of these nuclear receptors was noticed in a variety of cancers. For example, PXR was found to be upregulated in some breast cancer patients (Pondugula & Mani, 2013). Similarly other nuclear receptors were also overexpressed in cancer patients (Chen et al., 2012). Activation of these nuclear receptors has been shown to upregulate multidrug transporters, resulting in resistance to chemotherapy drugs (Pondugula & Mani, 2013; Chen et al., 2012). Conversely, inhibition or downregulation of nuclear receptors resulted in decreased expression of multidrug transporters and sensitizes cancer cells to chemotherapeutic drugs (Pondugula & Mani, 2013; Chen et al., 2012).

Likewise, downregulation or inhibition of multidrug transporters has been shown to sensitize cancer cells to chemotherapy drugs (Pawlowski et al., 2013). It is indeed evident from combinatorial therapeutic approaches that some clinically used drugs or dietary components promote therapeutic efficacy of chemotherapy drugs, in part, by downregulating the expression/function of multidrug transporters (Siddiqui et al., 2011; Das, 1999; Buckingham, 1996; Zand, Rahimipour, Salimi, & Shafiee, 2008). Very recently, it was shown in canine lymphoid tumor cells that Masitinib, a tyrosine kinase inhibitor, reversed doxorubicin-resistance by inhibiting the function of MDR1 (Zandvliet, Teske, Chapuis, Fink-Gremmels, & Schrickx, 2013). Along the same lines, in canine mammary tumor cells, targeted downregulation of MDR1 using small interference RNA resulted in improved chemotherapy (Pawlowski et al., 2013).

Table 3. Analysis of gene expression of multidrug transporters in canine lymphoma (OSW, 17-71 and GL-1) and canine mammary tumor (CMT27, CMT28 and CMT12) cells. P, present; ND, not detected; NT, not tested; MDR, multidrug resistance protein; MRP, multidrug resistance-associated protein.

<table>
<thead>
<tr>
<th></th>
<th>MDR1</th>
<th>MRP1</th>
<th>MRP2</th>
<th>MRP3</th>
<th>MRP4</th>
<th>MRP5</th>
<th>MRP6</th>
<th>MRP7</th>
<th>MRP8</th>
<th>MRP9</th>
</tr>
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<tr>
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<td>P</td>
<td>ND</td>
<td>P</td>
<td>P</td>
<td>NT</td>
<td>ND</td>
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<tr>
<td>17-71</td>
<td>P</td>
<td>P</td>
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<td>P</td>
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<td>P</td>
<td>P</td>
<td>P</td>
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<td>NT</td>
<td>ND</td>
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<tr>
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<td>P</td>
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<td>P</td>
<td>P</td>
<td>NT</td>
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<td>ND</td>
<td>NT</td>
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</table>

Figure 3. RT-PCR for gene expression of multidrug transporters in dog liver under optimized conditions. Single band was observed at the expected size. Identity of the bands was verified by sequence analysis. M, 100-bp ladder; MDR, multidrug resistant protein; and MRP, multidrug resistance-associated protein. Lane 2 (MDR2) was removed due to lack of relevance to this study.
It is conceivable from the above studies that the nuclear receptors and/or multidrug transporters may be upregulated and contributing to chemoresistance in canine lymphoma and mammary tumors. In addition, modulation of these receptors and/or transporters, could be a beneficial approach to combat chemoresistance in canine lymphoma and mammary tumors. However, the expression of these receptors and transporters has yet to be fully characterized. The current study addresses this gap in knowledge. It is hoped that this study lays a foundation for explaining a mechanism of chemoresistance as well as providing an insight to improving chemotherapy in canine lymphoma and mammary tumors.

It remains to be determined which nuclear receptors and multidrug transporters are differentially expressed and upregulated in canine lymphoma and mammary tumor cells compared to normal cells. Our future studies using quantitative RT-PCR will enable us to obtain a comparative gene expression profile in the canine tumor cells relative to normal cells. Moreover, our lab has recently discovered some novel drugs and dietary supplements that sensitize canine lymphoma and mammary tumor cells to chemotherapy drugs. It is possible that these novel drugs and dietary supplements chemosensitize the cancer cells by downregulating the expression of multidrug transporters and/or nuclear receptors. We seek to conduct quantitative RT-PCR studies to determine whether these compounds or supplements downregulate nuclear receptors/multidrug transporters to enhance chemosensitivity. Simultaneously, we will also study the function of MDR1 and MRPs to determine the ability of these novel compounds and supplements to inhibit the activity of multidrug transporters to enhance the chemosensitivity.

Acknowledgments

This work was supported by Auburn University Start-up Funds (SRP), Auburn University Animal Health and Disease Research Grant (SRP) and Auburn University-Intramural Grant (SRP). OSW T-cell lymphoid tumor cell line was provided by Dr. William Kisseberth, Ohio State University. GL-1 and 17-71 B-cell lymphoid tumor cell lines were gifted by Dr. Steven Suter, North Carolina State University.

References


RESTORING RIPARIAN HABITAT IN AN URBAN SITE IN PRICHARD, ALABAMA: IMPLICATIONS FOR LOCAL GOVERNMENT AND COMMUNITY COLLABORATION

Maria K. Hines & Charlene LeBleu

Abstract

As urban centers continue to develop and grow, local municipalities must turn their attention to the issue of natural area restoration and water quality. Natural areas are vital to the life of urban dwellers because they can allow people to have connections to something larger than themselves; nature supports recreation, relaxation, and spiritual attributes. While municipalities are focused on the issue of restoration and water quality, Alabama State laws do not provide a uniform system for the restoration of these areas, often resulting in conflict between communities and government. However, there are a number of resources available for local municipalities, including riparian buffer ordinances, that help to maintain a healthy riparian buffer zones. Riparian buffer ordinances are one of the most cost effective ways to protect the health of ecosystems, improve stream accessibility, and protect the welfare of citizens (Wenger & Flower, 2000). Involvement by landscape architects, other professionals, and public groups in the early planning stages of restoration can bridge the gap between policy and communities. This study is an examination of the use of riparian buffer ordinances and zones as a design method in the built environment and its impact on water quality and society. To illustrate these impacts, I will reference two policies, Stream and River Corridors: Creating Effective Local Riparian Buffer Ordinances and The City of Auburn Stream Buffer Ordinance, and their application to a urban site in Prichard, Alabama.

The project attests that riparian buffers are vital to the overall water quality of a city and, if maintained, can help to provide wildlife diversity, aesthetic beauty, recreational opportunities, and a strong community cohort.

Introduction

The health of our state’s water bodies depends considerably on the lands that surround them. Through protecting natural vegetated areas along streams, referred to as riparian zones, local municipalities can buffer water bodies from the negative effects of nonpoint source pollution. A riparian buffer, or stream buffer, is a permanently vegetated transition zone along forested lands adjacent to streams. It functions primarily to intercept and slow runoff, stabilize stream banks, and provide food and shelter to wildlife. Often a part of an overall watershed approach, stream buffers also provide a range of other environmental, economic, and social benefits including trapping and removing nutrients and contaminants, storing flood waters, improving aesthetics, and offering recreational and educational opportunities in localized situations. Despite their importance, three key obstacles still stand in the way of effective riparian buffers. First, Alabama state laws do not provide a uniform system for the protection of riparian buffers. Second, concerns over property rights cause many to avoid employing buffer ordinances for fear of mandated public access to private property, or restrictions
that would limit land use. Lastly, a lack of public information and education has led to engineered water-quality practices and a decrease in community participation (Wenger & Fowler, 2000). However, for municipalities who are looking to restore riparian habitat and improve water quality, riparian buffer ordinances can offer guidance and enforcement mechanisms for local government.

The City of Auburn, Alabama, Stream Buffer Ordinance is an effective stream buffer ordinance that can be utilized, along with Wenger & Fowler’s (2000) Protecting Stream and River Corridors: Creating Effective Local Riparian Buffer Ordinances, to offer aid for city and county governments in Alabama. Auburn’s stream buffer ordinance is an example of an overlay zoning ordinance. These ordinances are most effective for counties who have an existing zoning ordinance, because they impose restrictions on the affected portion of property while still enforcing other zoning classifications. The ordinance aims to “establish minimal acceptable requirements for the design of buffers to ensure that the stream and adjacent land will fulfill their natural functions; to reduce land development impacts on stream water quality and flows; and to provide for the environmentally sound use of Auburn’s land resources” (City of Auburn, 2012, p.32). The ordinance accomplishes these goals by requiring buffers on each side of perennial and intermittent streams, by applying a variable width buffer based on the size of the upstream drainage basin, and by dividing the buffer into three zones to determine the permitted uses. Moreover, the ordinance provides accommodations for landowners who lose buildable land; these mitigation techniques include the installation of structural best management practices (BMPs), controlled impervious surfaces, open space development, stream restoration, stream preservation, and wider buffer widths where encroachments occurs in other areas on the development site. Auburn’s stream buffer ordinance is a good example of an effective model ordinance in that it meets minimum standards set forth by the Environmental Protection Agency (EPA), has clear variables, is flexible, and offers variance procedures. When paired with Wenger and Fowler’s (2000) document, this ordinance helps local governments to gain additional insight on the characteristics of buffers, the components of an effective ordinance, case studies of effective buffer ordinances, tools to protect riparian buffers, and variance procedures. This project seeks to apply knowledge from riparian buffer research, landscape architecture practices, and community partnerships, to a site in order to restore 350 feet of an urban stream site to its natural function as an aquatic and terrestrial habitat.

**Background**

The project was developed in the City of Prichard, Alabama, located in Mobile County and in the Eight Mile Creek Watershed (Figure 1). Since 1990, Prichard has experienced serious social and economic decline due to a decrease in population, high unemployment rate, loss of investment, and lack of educational attainment among residents. The city has several strengths including the University of Mobile campus; 150 acres of city-owned land designated as Africatown Park; 1,100 acres of undeveloped land available, and long-term family owned businesses (Figure 2). The city maintains a unique history, culture, and strong public will to create a better quality of life for its residents. For these reasons, redevelopment of city assets and protection of natural resources have become key priorities of city officials. This newfound interest in natural resource investment, along with Prichard’s political will to attract new development, will undoubtedly lead to increased urbanization and an increased need to consider water quality.

![Figure 1. Location of Prichard (blue circle) in Alabama.](image-url)
The landscapes within Prichard must be considered not only in terms of their natural functions but also their potential recreational use as well. Through installing stable and effective riparian buffers, local governments can combat negative consequences of urbanization and improve the quality of groundwater and surface water for residents. At a citywide level, the primary natural resources are parcels of undeveloped woodland and marshland, as well as creek and estuarine environments (City of Prichard, 2006). At a more local level, Prichard contains five miles of impaired streams comprised of the semi-braided, perennial Eight Mile Creek and larger Chickasaw Creek tributary streams located within the Eight Mile Creek Watershed. The Eight Mile Creek watershed consists of the southern third of the Eight Mile, most of the Whister community, and the Bessemer community. One tributary in this system, Reading Creek, a first order stream, runs along the recently improved Jackson Reading Park, the location of the project (Figure 3).

Jackson Reading Park is located on Newton Avenue in the Whister community in Prichard, Alabama. Presently, visitors are led to the park along Newton Street, an unpaved access road that dead-ends and lacks organized parking. Currently, what the park lacks in organization is made up by the tranquil and modest nature of the site. The main entrance of the park is flanked by two iron gates, and a walking trail marked by a brick boarder guides visitors to the other features of the park including a gazebo, swings, and a butterfly garden. The backside of the park is adjacent to Reading Creek. Prior to the project, Reading Creek suffered from erosion and invasive species (Figure 4). The drainage area is approximately 680 acres. Overall, the park is in need of improvement in parking, walking, and drainage. Conceptually, the goal is to improve stream conditions through adjusted morphological conditions for water and sediment transport and the restoration of a riparian buffer.

In August 2011, the Mobile Bay National Estuary Program, along with Auburn University partners, applied for the Five Star Restoration Grant Program sponsored by the National Fish and Wildlife Foundation in order to restore a stream and riparian habitat in Prichard. A key feature of the proposal was its proactive, participatory planning which integrated the values and experiences of both private and public stakeholders to achieve synthesized goals and an inclusive vision of the site. Stakeholders included the City of Prichard, the Mobile Baykeeper, Prichard Environmental Restoration Keepers (PERK, a local grass roots organization), Coastal Alabama Clean Water Partnership representative Christian Miller, Auburn University’s School of Forestry and Wildlife Sciences and Department of Landscape Architecture, and the Alabama Cooperative Extension System Water Quality group. Through informed negotiation, the following goals were approved: restoration of Reading Creek to its natural function, revitalization of aquatic and terrestrial habitat through the installation of a riparian buffer, installation of an educational site for showcasing LID and BMP mitigation techniques would be established, and public outreach initiatives would be included to educate the community about ecology and landscape stewardship. These goals were set into motion in August 2011 and were completed in March 2013; the process is described below.

**Methods and Procedures**

To restore Reading Creek to its natural function and revitalize aquatic and terrestrial habitat 350 linear feet of stream bank and shoreline were stabilized, invasive plant species were removed, native plants and trees were planted, and a riparian buffer was established. The vegetation selected for riparian buffers is influenced by the purpose of the buffer. While buffers covered by grass can sufficiently trap sediment and contaminant, trees and shrubs are better suited for capturing
pollutants and providing habitat. As a result, buffers should be forested in order to protect wildlife, remove sediment, and filter pollutants. Moreover, invasive species should be removed, and native plant species are preferred. Placement of vegetation should follow the guidelines set forth by the three buffer width zones (U.S. Environmental Protection Agency, 2006). When necessary, restoration should be conducted to improve the stream bank (Wenger & Fowler, 2000). Through achieving these goals the riparian buffer surrounding Reading Creek will be able to provide food, shade, and large woody debris to help maintain moderate water temperatures for wildlife.

The riparian zone was modeled after the requirements of the City of Auburn Stream Buffer Ordinance, which states “Stream buffer width should be based upon the size of the upstream drainage basin” (City of Auburn, 2012, p. 32). With this characteristic in mind, the buffer width was determined based upon an upstream drainage basin of ≥ 640 acres with a streamside zone of 25 feet, a managed use zone of 50 feet, and an upland zone of 25 feet for a total buffer width of 100 feet. Given these dimensions, the buffer extends into Jackson Reading Park.

Following the restoration of Reading Creek and installation of a riparian buffer, other mitigation techniques were installed to intercept runoff, filter pollutants, encourage infiltration, and provide an educational site for LID and BMP practices. Mitigation techniques included the introduction of storm water wetlands, rain gardens, the preservation of wooded area north of Newton Street, and impervious surfaces were reduced to a ratio of ≤ 25%. These techniques work with the nature of the park to manage storm water in a way that works with the natural movement of water within the site. In addition, all structural BMPs as part of the project have an educational component that includes signage explaining how they manage storm water, restore wildlife habitat, and improve overall water quality for the city.

Throughout the course of the project, the City of Prichard and community leaders were provided with information on stream restoration, watershed modeling, and low impact development strategies through hands-on workshops and design charrettes that explored “what if” scenarios. For example, in October 2012, the Mississippi-Alabama Sea Grant Consortium and a team of Auburn University faculty hosted a Watershed Modeling-Low Impact Development Workshop for Costal Sustainability in the Prichard City Council auditorium. The workshop addressed existing physical conditions and land use modeling within the Eight-Mile
Creek Watershed, water quality conditions of the Eight-Mile Creek Watershed, LID practices, innovative planning initiatives for model stream buffer policies, and implementation of these strategies through a hands-on design charrette. Evaluation of these events consisted of a form completed by each participant. Participants were asked to rate each presentation, identify the most useful part of the workshop, rank how much they had learned, and provide suggestions for the future (Kalin, 2012). Along with educational components, community outreach events were set up through the Mobile Baykeepers, Coastal Alabama Clean Water Partnership, and PERK. Together, these groups engaged in trash cleanup, restoration work, water quality monitoring, and grass plantings. The success of these events can be measured based upon the number of adult volunteers in the project.

**Results and Discussion**

The restoration of Reading Creek was accomplished through stabilizing 350 linear feet of stream bank and shoreline. Moreover, during the course of the project 150 volunteers planted 2,500 native plants and removed 90% of all invasive species; creating a healthy riparian buffer for aquatic and terrestrial wildlife. Additionally, mitigation techniques included the introduction of storm water wetlands and rain gardens, the preservation of wooded area north of Newton Street, and the limitation of impervious surfaces to 25% of the site; the mitigation techniques increased the site’s ability to penetrate groundwater (Figure 3). As a collection, these demonstration techniques showcase LID and BMP practices and provide a place for citizens to learn about preserving and restoring the natural environment.
Overall, the educational outreach initiatives served as a platform for communication and aimed to change the citizen’s perception of riparian buffer zones. To demonstrate, during the Watershed Modeling-Low Impact Development Workshop for Costal Sustainability participants were asked to complete a pre- and post-workshop survey that covered topics of land use modeling, LID stream buffer knowledge, and the state of the Eight-Mile Creek Watershed. In the pre-workshop survey, the mean score was 69% and the lowest score was 20%. In the post-workshop survey, the mean score was 90% and the lowest score was 60%. After completing the workshop, there was a 21% improvement in understanding LID techniques and practices. In addition to the pre- and post-workshop surveys, participants were asked to fill out an evaluation form after completing the workshops. The feedback from the participants was very positive and the workshop was seen as useful in terms of creating awareness of LID best management practices and showcasing new research for watersheds on a municipal level. To illustrate, when asked what they gained from attending the workshop, the totality of participants indicated the usefulness of stream restoration, development of buffer zones, GIS modeling, and LID and BMP design strategies. Of the 17 respondents, 13 agreed that they would be interested in attending another workshop. Other comments highlighted how much participants enjoyed the hands-on quality of the design charrette.

Conclusion

The restoration of Reading Creek by use of a riparian buffer contributes to the understanding of how restoration can be used to help bridge the gap between policy and communities. Through involvement by community members and civic leaders during the planning stages of design, conflict was avoided, special qualities of a site were maintained, and public interests were considered. The workshops proved to be one of the most effective platforms for communication and presentation of information to community and local government council members. Likewise, the charettes played a critical role in teaching community members how to apply LID restoration practices to natural areas and water bodies. The results of this paper suggest that riparian buffers are a viable tool for restoration. Moreover, when communities are engaged early on by policymakers, a dialog can be fostered which can result in new development. In the situation of Reading Creek, a conversation about riparian buffers resulted in a collaborative project that appealed across audiences and demographics; providing that, communication and design, when coupled, are powerful tools that can be utilized with riparian buffer ordinances to improve water quality.

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References


Buffering Strategies in the Delivery of Bad News: Managing Identity in Interaction

Trenton M. Fisher & Robert R. Agne

Abstract
This study explores the delivery of bad news in a telephone conversation between a sister and brother, Megan and Daniel, in which Megan tells Daniel that tickets to a conference are sold out. Analysis focuses on how Megan’s strategies as the bearer of bad news and Daniel’s participation in the conversation show that giving bad news is an interactional activity. In discussing implications for our analysis, we argue that this interaction reveals that Megan is managing her own identity as a good sister while also maintaining what we describe as a relational identity between her and Daniel.

Introduction
This study is a qualitative, interpretive project, employing what is known as discourse analysis in communication research—the study of transcribed naturally-occurring talk for the sake of developing arguments about communication-related issues (Gee, 2011; Sanders, 2005). The goal of our study is to use this method of analysis in examining a casual telephone conversation between a brother and a sister in which the sister, Megan, has some disappointing news for her brother, Daniel, that tickets to a conference he wants to attend are sold out.

In analyzing how Megan’s delivery of bad news plays out in her conversation with Daniel, we describe Megan’s delivery of the news in terms of buffering strategies. Our argument is two-fold. First, we contend from our analysis that these strategies contribute to research on the delivery of bad news as well as buffering as a communicative practice. We also argue that these buffering strategies serve to manage and maintain both Megan’s individual identity as well as the relational identity which is formed by her interaction with her brother.

Literature Review
Research on the delivery of bad news often refers to Rosen and Tesser’s (1972) work with undesirable messages as its starting point (Dibble & Levine, 2010). Building on this foundation, studies of delivering bad news are commonly found in research about doctor/patient communication (Maynard, 2003; 2004). Studies have focused on doctors’ communication style in giving bad news (Shaw, Dunn, & Heinrich, 2012), the dilemma of delivering bad news honestly but not harshly (Del Vento, Bavelas, Healing, MacLean, & Kirk, 2009), and best practices for giving bad news (Henry, Holmboe, & Frankel, 2013; Hudak, Clark, & Raymond, 2013). Other contexts for delivering bad news include the workplace (French & Holden, 2012; Wagoner & Waldron, 1999) and television and radio news (Lowery, 2008; Stone & Grusin, 1984). Context aside, research has also explored people’s reasons for being reluctant to convey bad news (Dibble & Levine, 2013) as well as the turn-taking structure in bad news conversations (Benjamin, 2012; Maynard, 1997).

Our study takes a different approach than most previous research on delivering bad news in that it treats the delivery of bad news as an interactional accomplishment. We focus on the interactional nature of the delivery of bad news because this is not the kind of communicative situation in which one person gives news to another as if it is contained in an envelope or broadcast to a mass audience. As Maynard (1997) has shown, the receivers of the bad news take a conversational role as the news is delivered to them. For example, they may ask questions to clarify or elaborate on the news, or they may add information that changes the severity of the news. In this sense, perhaps the term “delivery” is inaccurate because when the interaction of the participants is taken into consideration the news is
socially constructed as good or bad rather than simply delivered from one party to the other. We also focus on what messages accomplish, which follows Tracy’s (2011) notion of discourse doing identity-work. For Tracy, communication is seen as more than information; it also functions to shape the identities of the interactants. Tracy calls this a “rhetorical approach” to the relationship between discourse and identity, where communicators are viewed as goal-oriented and, consciously or not, talk in ways that reach some ends and avoid others (see also, Agne & Tracy, 2009). Foundational to Tracy’s idea of identity-work is Watzlawick, Beavin, and Jackson’s (1967) work on content and relational dimensions of messages. Watzlawick et al. (1967) developed the argument that all utterances convey both literal information (i.e., content) as well as implicit claims about the relationship between the communicators, largely by how the message is spoken (e.g., tone of voice, speech rate, other vocal or non-vocal cues). Tannen (1984) later described these dimensions as the message and the meta-message, where the meta-message elaborates on and can even contradict the message. The message (i.e., content) conveys what is said, and the meta-message (i.e., relational dimension) conveys what is meant. For example, saying something like “excuse me” to someone could take on many different meanings depending on how it is said (e.g., an apology, a request for an apology, an interruption, a correction, etc.).

Tracy (1997; 2011) expands on the content-relational/message-metamessage work in two ways. First, while Watzlawick et al. (1967) and Tannen (1984) focus on single utterances, identity-work considers more than single utterances and looks to broader communicative practices. Examples include offering social support (Goldsmith & Fitch, 1997), crisis negotiation (Agne, 2007), calling for help (Tracy & Agne, 2004), small talk before a business meeting (Mirivel & Tracy, 2005), and plastic surgeon/patient consultation (Mirivel, 2008). Second, identity-work focuses on the multi-dimensional character of identity in the interaction. Our identity is a collection of personal traits, relationships, social roles we take on, and cultural backgrounds. In addition, talk functions to shape not just our own identity but those of others (present or not present) as well.

The communication practice we consider in this study is the delivery of bad news. The research questions we ask are as follows: (1) What strategies does Megan use to accomplish this task as she breaks the bad news to her brother, and (2) How do these strategies function to shape either partner’s identity?

Method and Materials for Analysis
In qualitative research, including the study of discourse, it is important for researchers to examine people participating in the communication situation not as subjects but as people relating to each other, making sense of their world naturally and collaboratively (Lindlof & Taylor, 2011). Therefore, data for discourse analysis is recorded and transcribed naturally-occurring talk so that claims can be made by referring to specific moments of what speakers say and how they say it. As part of a class project in discourse analysis, one of Megan and Daniel’s phone conversations was recorded. Transcriptions for the project come from an hour-long conversation. As in most discourse analyses, transcription employs a common symbol system that captures what people say as well as their intonation, pitch, emphasis on certain words or sounds, vocal fillers (e.g., “uh” and “uhm”), elongation of vowel sounds, loudness, false starts, and overlapping speech (Psathas, 1995). See Appendix for a list of symbols and meanings.

Background Information
Megan (22 years old) and Daniel (24 years old) have a very close brother/sister relationship. They regularly talk on the phone and spend a lot of social time together. In this conversation, Daniel asks Megan what her plans are for the coming weekend. She informs him that she is going to attend the Strong Love Worship Conference in a nearby city, which features a concert by the Strong Love Worship Band. Both are fans of the band and frequently attend Strong Love church services that are broadcast at their local church. Daniel spent a semester attending the Strong Love School of Ministry based in California. The worship band travels the world playing at churches and conferences, often in front of enormous crowds, making the events feel more like rock concerts than church services. In the telephone conversation between Megan and Daniel, after Megan reports that she has her ticket to attend the conference, Daniel expresses his desire to also attend. Because he has spent a year in ministry training at Strong Love Church and has often expressed his love for the band, his desire to attend the conference is very strong. Megan, however, knows that the conference is sold out of tickets, and she must deliver this bad news to Daniel.

Analysis
Bad news is somewhat relative. Megan’s news is not necessarily that Daniel can’t go to the conference, but rather that tickets are sold out. This situation is not unlike classic discourse analytic work that studies how people decline invitations without directly refusing (Davidson, 1984; Johnson, 2008). In this conversation, Daniel communicates his desire to attend
the conference, which prompts a response from Megan in which she assesses the feasibility of his plans. Her response introduces information into the conversation that creates two problems. One is that the news is bad for Daniel. The other is that Daniel’s potential jealousy and Megan’s potential guilt may threaten the siblings’ relationship.

Claims of Powerlessness

One way Megan manages these problems is through discursive moves of claiming powerlessness. This is shown in the following excerpt in which Daniel has just made it clear that he wants to attend the conference.

Excerpt 1:

54  Megan: (well) the only thing is? is that they’re sold out of tickets.
55  Daniel: (3.0) oh really?
56  Megan: yeah (2.0) yeah. I would’ve loved for you to come with me.

By telling Daniel on line 54 “they’re sold out of tickets,” Megan indicates that there is a problem with Daniel’s desire to attend the conference. She introduces the problem with an indirect warning in both words and tone. “Well” is spoken with a high pitch (“!well”) and “the only thing is?” has the sound of a question, both of which could be heard as a softening or buffering of bad news to come, suggesting that Daniel brace himself for it. After hearing the news, Daniel inquires about Megan’s previous utterance. The nature of Daniel’s inquiry on line 55, characterized by a three-second pause and quieted speech, conveys disappointment towards Megan’s report on line 54 that the conference is already sold out. In addition, Daniel may be thinking about how to resolve this problem. That tickets are sold out does not necessarily mean he can’t go.

Daniel’s disappointed and pensive response in line 55 triggers Megan to buffer her news that Daniel will not be able to attend the conference. Her saying “yeah” on line 56 confirms to Daniel what she stated on line 54, that the conference is in fact out of tickets. It is the rest of Megan’s utterance that claims powerlessness. The conditional statement “I would’ve loved for you to come with me” tells Daniel that ordinarily, she would want him to attend, but this is not an ordinary circumstance. In other words, Megan is saying, “Ordinarily, I would love for us to go together, but since they are sold out of tickets, we can’t, and there is nothing I can do to change that.”

Claims of Uncertainty

Another excerpt reveals a buffering strategy of claiming uncertainty. Right after Megan tells her brother that she would have loved for him to come with her (Excerpt 1, line 56), Daniel presses her sister for more information.

Excerpt 2

57  Daniel: (you) think there’s a way I could get a ticket?
58  Megan: I don’t know people are trying to buy ‘em and sell ‘em on Facebook.

Daniel’s follow-up in line 57 elicits another buffering strategy from Megan that leaves little to no hope for him. After explicitly stating that the concert is sold out (Excerpt 1, line 56), Megan responds to Daniel in line 58 saying, “I don’t know.” Then she indicates that there is a chance he could purchase a ticket from the internet (“people are trying to buy ‘em and sell ‘em on Facebook”). By saying “I don’t know,” particularly in elongating “know,” and “I don’t think,” she claims to be uncertain about whether or not Daniel will be able to find a ticket. Uncertainty is maintained in her reference to others buying and selling tickets on Facebook. She suggests the internet as a way to acquire a ticket but in no way guarantees success. In fact, she suggests buyers outweigh sellers, reducing probability (line 59, “I don’t think anyone’s selling their tickets”). This stance of uncertainty allows Megan to softly maintain the improbability that Daniel will be able to attend the conference. Along with a claim of powerlessness, her uncertainty reaffirms that the situation is out of her control.

Attempting to Close the Subject

A third buffering strategy is Megan showing an attempt to bring closure to the subject. Megan and Daniel’s conversation moves on to other topics, but Daniel returns to the topic of the concert, thus requiring Megan to continue buffering.

Excerpt 3

86  Daniel: right (GA:) I wanna go so badly.
87  Megan: I know. I mean I can look up and see: but I don’t (2.0) I don’t think (2.0) that (1.5) it I don’t think there’s any tickets left.
88  Daniel: mhm
89  Megan: you know?
90  Daniel: yeah (2.0)
91  Megan: so:
92  Daniel: we’ll ok a: y. (2.0)
93  Megan: uh huh (1.0)
94  Daniel: yea:h
Daniel's persistence in returning to the topic can be seen in line 86 as he suddenly, loudly, and with emphasis says, “GA:::H,” elongating the sound. Megan displays powerlessness and uncertainty again in line 87, telling her brother that she could look into the matter but has doubts of success. When Daniel responds with, “mhm,” on line 88, Megan quietly clarifies that Daniel understands her previous utterance by saying “you know?” (line 89). Daniel responds “yeah,” followed by a two-second pause (line 90). In fact, the entire exchange is filled with pauses that are so uncommonly long for the free-flowing conversation of Megan and Daniel (lines 87, 92, 93, and 96) that they can easily be interpreted as “awkward” pauses. On line 91, Megan uses the word “so::” perhaps to indicate that she wants to talk about something else. Megan’s “uh huh” on line 94 and the utterance “y::eah.” on line 96 also indicate that she is attempting to put an end to the topic because little is being said. Utterances are exchanged but nothing is being talked about.

Megan’s utterances in this excerpt can be seen as vocal fillers that attempt to close the subject without saying outright that she does not want to talk about it anymore. When Daniel says, “um (3.0) well u::h what else are you gonna do?” Megan has successfully closed the subject (for the time being, anyway), leaving Daniel to change the topic. It would be unkind of Megan to continue talking about the fact that Daniel can’t make the trip, for the time being. When Daniel says, “um (3.0) well u::h what else are you gonna do?” Megan has successfully closed the subject (for the time being, anyway), leaving Daniel to change the topic. It would be unkind of Megan to continue talking about the fact that Daniel can’t make the trip, but it would also be insensitive to move on to another topic without giving Daniel the opportunity to come to peace with the disappointing situation he is in.

Discussion

Our analysis describes Megan’s delivery of bad news to Daniel in terms of buffering. Little research has examined the delivery of bad news in casual conversations like this of close siblings. The strategies Megan uses are not found in research on doctor/patient interaction. Most of the research on delivery of bad news is concerned with message effectiveness and receivers’ experiences in learning about the news. Prior research does describe how doctors provide bad news, but it does not explore how their practices may include buffering strategies. For instance, a doctor may employ claims of powerlessness and uncertainty if prognosis is unclear and the chances of recovery, success, or healing is beyond the power of the doctor. Megan’s strategy to change the subject and move on would also be interesting to look for in doctor/patient interaction. Some doctors may not allow time for the patient to process the bad news or may rush to attend to other patients to remove themselves from the situation.

In the television and radio news context, delivery of bad news is the least interactional. Broadcast news is usually examined in terms of framing strategies (Lowery, 2008; Ghanem, McCombs, & Chernov, 2009), shaping the information as good or bad. In the organizational context, French and Holden (2012) suggest an emphasis on positive organizational climate in conveying bad news during an organizational crisis, expanding on the “sandwich” approach in which bad news is surrounded—or buffered—by positive or hopeful information. In contrast to research in these contexts, our study sees buffering strategies within the interactional process.

One study on family interaction does describe a conversational strategy as buffering, though not as part of the practice of delivering bad news. Tannen (2004) argues that family members use pets as resources to mediate their interactions with each other and maintain solidarity. For example, in one instance, a husband avoids conflict with his wife by using humor and apologizing by talking as if he were the dog. Our description of buffering strategies is different than Tannen’s because Megan is left to her own devices with no pet at hand to use as a resource. Also, Tannen’s description of buffering in interaction accomplishes something different than ours. While Tannen suggests that buffering maintains family peace, we would argue that buffering also has implications for identity. The bad news certainly has impact on the receiver, but perhaps more important is how the news is given and processed in the interaction and how it impacts the giver of the news as well as the relationship between the giver and the receiver. This is not unlike French and Holden’s (2012) main argument that news can be buffered to maintain organizational identity, but identity in our study is more of an interpersonal concern.

Here, returning to Tracy’s (2011) research on identity-work is useful. She describes identity as having four aspects, two of which are relevant for our study of Megan and Daniel’s conversation. Personal identities are personality traits a person possesses. Relational identities are those characteristics that mark specific relationships such as friendships, parent/child relationships, lovers, or sibling relationships. Some of these characteristics include the power differential in the relationship and level of closeness. Institutional identities are those roles we take on in social life such as teacher, lawyer, nurse, and student. Finally, master identities are those cultural aspects of the self, such as race, age-group, religion, ethnicity, nationality, etc.

In Megan and Daniel’s conversation, Megan managed her personal identity and sibling relational identity simultaneously. Claiming powerlessness and complete lack of knowing would have washed Megan’s hands of the situation, but she does not claim a complete lack of knowledge. Instead, by claiming powerlessness and
uncertainty, she conveys a glimmer of hope for Daniel, albeit a false one. This also says to her brother that she too wants him to go, presumably so they could go together. However, it is not out of the question that Megan may have deliberately waited to tell her brother about the conference (for whatever reason) until after she purchased her own ticket, and she could be using buffering to prevent him from discovering that she intentionally left him out. Either way, buffering strategies shape her personal identity as an inclusive, caring person who wants what her brother wants. In addition, Megan’s buffering strategies also serve to maintain her relationship with her brother. Claiming relative powerlessness and uncertainty creates a relational identity of equality and solidarity because they align with Daniel’s relative powerlessness and uncertainty in getting a ticket. Also, Megan’s indirect efforts to close the subject can be seen as an attempt to do what is best for the relationship.

**Conclusion**

While the study of delivering bad news is typically done in contexts with more serious consequences, we see no less interesting strategies in casual conversations like the one between Megan and Daniel. Also, while we analyze the delivery of bad news through Megan’s strategies, this study additionally shows how Daniel, the recipient of bad news, also participates in identity shaping. In other words, the delivery of bad news is an interational achievement, not a simple delivery of information.

When people talk to others about their troubles, they sometimes use what Jefferson (1984) calls a “buffer topic” in the form of a joke or anecdote associated with the trouble being told in order to lighten the situation. Criticism can be buffered according to Tannen (2004), and so can organizational crisis according to French and Holden (2012). Our study compels us to suggest that buffering strategies in the delivery of bad news could called “identity buffering,” which suggests discourse practices in the bearing of bad news accomplish more than conveyance of information.

**References**


### Appendix

Conversation was transcribed using a simplified version of the Jeffersonian transcription system (Psathas, 1995). Transcription symbols include:

- Falling intonation
- Rising intonation at the end of a word, as if sounding like a question
- Marked rise or fall in pitch at the beginning of a word
- Continuing intonation
- An abrupt cut-off
- Prolonging of sound

never
Stressed syllable or work
>word<
Quicker speech

_o_
Softer speech

_hh_
Aspiration or laughter

_.hh_
Inhalation

[]
Simultaneous or overlapping speech

=
Contiguous utterances

(·)
Micro-pause, 2/10 second or less

(3.5)
Numbers in parentheses indicate a timed pause within or between turns

( )
Nontranscribable segment of talk or transcriber doubt

(( ))
Transcribers comment or description
Abstract

The focus of this paper is the use of aerodynamic forces for CubeSat orbit control. Such a control scheme would enable fleets of CubeSats to fly in formation without the need for thrusters. A preliminary mathematical analysis of satellites in circular orbits at different altitudes showed that very small altitude differences could result in comparatively large changes in satellite separation over a reasonable time interval. A numerical-integrator-based software simulation was developed to provide a more accurate orbit model along with a control algorithm for changing satellite separation. Simulation results indicated that orbit control using aerodynamic forces in low Earth orbit was feasible. The aerodynamic forces would be weak enough that at higher altitudes (simulations at 600 km), maneuvers would take days or weeks to complete, allowing operators to control the satellites entirely from the ground. Based on observed satellite positions, ground operators could specify to the satellites what orientations to assume and for how long to hold these orientations, eliminating the need for complex onboard computation.

Introduction

As technology has progressed, CubeSats have become increasingly prevalent. While a single CubeSat may not be able to outperform a larger satellite, CubeSats have the capability to operate in fleets due to their relatively low cost and size, as many CubeSats could be built for the cost of one larger satellite. Fleet operation allows for a resolution of observations in time and space, meaning that a phenomenon could be observed from several different positional vantage points or at different points in time. This allows for the collection of more comprehensive scientific data by fleets of satellites as compared to a single satellite.

Orbit control is necessary for fleet operations, and conventional orbit control methods generally require precise attitude and position determination, autonomous control by the satellite, and the firing of thrusters. However, because most CubeSats ride as secondary payloads on larger missions, risk mitigation constraints often prohibit the inclusion of CubeSat thrusters. The purpose of this study is to show that satellite orbits can be controlled without thrusters, facilitating formation flight. This control can be achieved by generating differential aerodynamic forces on two CubeSats initially along the same low Earth orbit, thereby altering their orbits by different amounts. Orbit control using aerodynamic forces does not require satellites to have positional knowledge and does not mandate the precise attitude control or high power budget associated with thruster. This greatly simplifies the design of the satellites, making this method of control ideal for low budget missions. By orienting a CubeSat such that the drag force is greater, the satellite can be made to drop to a lower altitude and consequently have a shorter orbital period than a similar satellite that began in the same orbit, but had less drag. This procedure could be used to increase, decrease, or maintain the separation between two satellites in the same orbital plane. The risks and space/mass requirements associated with a thruster system are eliminated by the use of these passive forces. Only a 3-axis attitude control system or deployable/retractable drag flaps would be required. These systems are producible by many CubeSat builders.

This study began with an analytical analysis of angular separation as a function of time between two satellites in the same orbital plane but at different altitudes. The equations of motion of the satellites were then calculated based on gravitational and aerodynamic forces, and a fourth order Runge-Kutta numerical integration algorithm was
utilized to integrate these equations. A control algorithm to produce a desired change in satellite separation was then developed, and its operation and effects were modeled by the numerical integrator. Data from the simulation were graphed and tabulated, and the feasibility of an aerodynamically based orbit control system was determined.

Environmental forces other than aerodynamic drag were ignored in these simulations because only aerodynamic drag is significant in inducing satellite separation. Most other environmental forces such as solar pressure, J2 (gravitational forces due to Earth’s oblateness), and magnetic hysteresis, are either extremely weak, cancel out over time, or affect both satellites equally, allowing them to be safely ignored. The Systems Toolkit (STK) software suite by Analytical Graphics, Inc., was utilized to verify that the ignorance of these forces generates only minimal error.

**Existing Literature and Expected Contributions**

Most existing literature focuses on the effects of aerodynamic forces on orbital decay, as the limited maneuvering capabilities provided by aerodynamic control (as opposed to thruster control) make this method unfavorable for many high-dollar missions. Most of the existing literature focuses on the effects of aerodynamic perturbations on a single satellite but does not address the concept of fleet control. Information regarding the effects and calculations of aerodynamic forces can be found in Klinkrad and Fritsche (1996), Vallado and Finkleman (2008), Cook (1965), and Gaposchkin and Coster (1988). Some existing literature addresses the concept of satellite constellation control using differential drag (Varma, 2011; Horsley, 2012; Daniel, N.J, du Plessis, J.J., and Steyn, W.H., 1996; Haiping, C. and Zhaokui, W., 2011), but the majority of this research is purely theoretical.

In some missions, such as NanoSail-D (Anderson, 2011), drag-inducing devices were utilized to expedite de-orbit, but not to maintain a formation of multiple satellites. Some missions have utilized aerodynamic forces to perturb satellite orbits to help maintain a formation, but little or no public domain literature exists regarding missions designed to demonstrate this method of fleet control. In most fleet-based missions, onboard thrusters were utilized for orbital maneuvering. If aerodynamic forces were utilized, they were considered merely as a secondary means of orbital perturbation. In missions that did not have onboard propulsion, aerodynamic forces were never utilized for accurate formation flight. In the AeroCube-4 mission (Gangestad, Hardy, and Hinkley, 2013), differential drag generated by deployable flaps was utilized to induce some separation between satellites after deployment, but not to maintain a precise formation. It is the intent of this paper to validate existing research by providing a detailed analysis of the effects of aerodynamic forces on satellite orbits and to provide a methodology and practical control algorithm by which a fleet of satellites can be controlled based on these principles.

![Figure 1. ∆θ between two satellites over time at various θ at 600 km altitude (r = 6978 km): Note: 1 degree ≈ 120 km.](image-url)
Numerical and Simulation Methods

Orbital Analysis

Earth’s gravitational force is by far the most powerful force that acts on satellites in Earth orbit. This force, $F_g$, is given by the equation

$$ F_g = \frac{G M_E m_s}{r^2} \quad (1) $$

where $G$ is the gravitational constant, $M_E$ is the mass of Earth, $m_s$ is the mass of the satellite, and $r$ is the distance between the satellite and the center of Earth.

From Equation 1, the equations governing satellite motion can be derived. A basic analysis of circular orbits provides a better understanding of fundamental orbital mechanics and preliminary numerical data regarding the behavior of satellites with different orbital conditions. In a circular orbit of radius $r$, translational velocity, $v$, is given by

$$ v = \sqrt{\frac{G M_E}{r}} = \sqrt{\frac{\mu_E}{r}} \quad (2) $$

where $\mu_E = G M_E$ is the gravitational parameter of Earth ($\mu_E = 398600 \text{ km}^3/\text{s}^2$). The angular velocity, $\omega$, of the circular orbit is given by

$$ \omega = \frac{\mu_E}{r^{3/2}} \quad (5) $$

Using the above equations and the binomial expansion theorem, the change in angular separation between two satellites, $\Delta \theta$, can be calculated by the equation

$$ \Delta \theta = (\omega_1 - \omega_2) \Delta t = \sqrt{\frac{\mu_E}{r^{5/2}}} \left( -3 \delta \right) \frac{\Delta t}{2r^{5/2}} \quad (4) $$

where $\delta$ is the difference between the satellites’ altitudes, and $t$ is time. Figure 1 shows $\Delta \theta$ over time for different values of $\delta$. In the course of a day, two satellites in circular orbits with an altitude difference of only 1 km will change their relative separation by 143 km. This rate is sufficiently more than necessary for the types of maneuvers discussed in this study.

Aerodynamic Effects

In this study, aerodynamic forces are relied upon to induce satellite altitude changes. Energy is added or removed from an orbit by orbital maneuvers that change the orbit’s semi-major axis. The specific energy, $E$, of an orbit is given by the equation

$$ E = \frac{v^2}{2} - \frac{\mu_E}{r} = -\frac{\mu_E}{2a} \quad \text{or} \quad E = -\frac{\mu_E}{2a} \quad (6) $$

where $a = -\frac{\mu_E}{2E}$ is the semi-major axis of the orbit. The orbital period, $T$, is given by

$$ T = 2\pi \sqrt{\frac{a^3}{\mu_E}} \quad (7) $$

Aerodynamic forces, $F_d$, are given by

$$ F_d = \frac{1}{2} C_d A_v \rho \infty v^2 \quad (8) $$

where $C_d = \frac{C_d A_v}{2m_s \rho \infty v^2}$ is the drag coefficient. The total drag force on a satellite, $a_d$, is given by

$$ a_d = F_d \quad \text{or} \quad \frac{1}{2} C_d A_v \rho \infty v^2 \quad (9) $$

Figure 2. JB2008 mean air density vs. altitude based on solar and geomagnetic activity (International Standard ISO/DIS 14222).
Here, \( a \) is the semi-major axis of the orbit. Solving for \( a \) gives

\[
E = \frac{v^2}{2} - \frac{\mu E}{r} = \frac{-\mu E}{2a}
\]

where \( a \) is the semi-major axis of the orbit. Solving for \( a \) gives

\[
a = \frac{-\mu E}{2E}
\]

Energy will be negative for elliptical orbits and positive for hyperbolic orbits (escape trajectories). Aerodynamic drag force acts parallel but opposite in direction to the velocity vector and thus reduces the energy of the orbit (makes it more negative) by an amount equal in magnitude to the work done by the drag force. This, in turn, decreases the value of \( a \), which decreases the orbital period, \( T \), given by

\[
T = 2\pi \sqrt{\frac{a^3}{\mu E}}
\]

A satellite with a shorter orbital period will have a greater average angular velocity and will catch up to a satellite with a longer orbital period.

Calculating Aerodynamic Drag Force

The aerodynamic drag force, \( F_d \), on an object is given by the equation

\[
F_d = \frac{1}{2} C_d A \rho_\infty v_\infty^2
\]

where \( C_d \) is the object’s drag coefficient, \( A \) is the area of the object perpendicular to the velocity vector, \( \rho_\infty \) is the free stream (ambient) density, and \( v_\infty \) is the free stream velocity (velocity of object relative to undisturbed airstream). The acceleration of the object due to drag, \( a_d \), can be calculated as

\[
a_d = \frac{F_d}{m_s} = \frac{C_d A \rho_\infty v_\infty^2}{2m_s} = C_B \rho_\infty v_\infty^2
\]

It is convenient to define \( C_n \) (the ballistic coefficient) in order to have a single coefficient that incorporates satellite geometry, mass, and orientation. Drag induced acceleration acts parallel to the velocity vector, so in vector form,

\[
\vec{a_d} = a_d \vec{v}_\infty = C_B \rho_\infty v_\infty (\vec{v}_\infty)
\]

As seen in Figure 2 (graphs from international standard ISO/DIS 14222), \( \rho_\infty \) can vary by up to two orders of magnitude at any given altitude based on

Figure 3. Lifetime of circular, equatorial orbits vs. initial altitude for low, medium, and high solar and geomagnetic activity if \( C_B = .01 \text{ m}^2/\text{kg} \) (International Standard ISO/DIS 14222).
solar and geomagnetic activity. Fortunately, large changes in average daily \( \rho_\infty \) occur over months and years, not days and weeks, allowing for the use of an average \( \rho_\infty \) for a given time period. Current simulations use the 1976 standard atmospheric density values for simplicity. As shown by Figure 2, \( \rho_\infty \) decreases exponentially with altitude. Thus, since drag force increases linearly with decreasing density, orbit lifetime will increase exponentially with altitude as shown in Figure 3.

**Equations of Motion**

The total acceleration vector \( \vec{a}_T \) is found by summing the gravitational and aerodynamic acceleration vectors \( \vec{a}_g \) and \( \vec{a}_d \)

\[
\begin{align*}
\vec{a}_g &= \frac{F_g}{m_s} \hat{r} = \frac{\mu_E}{r^2} \hat{r} = \frac{\mu_E}{r^3} \vec{r} \\
\vec{a}_d &= \frac{\mu_E}{r^3} \vec{r} + C_B \rho_\infty v_\infty \vec{v}_\infty
\end{align*}
\]  

Integrating the acceleration equation generates equations for \( \vec{r} \) and \( \vec{v}_\infty \) (satellite position and velocity) as functions of time. No closed form solution to this integral exists, so the acceleration equation must be integrated over a series of time-steps using a numerical integrator.

**Java Simulation**

This study employs a Java-based software suite, written using the NetBeans© Integrated Development Environment (Oracle Corporation, 2013) to model and display the satellites’ behavior in space based on initial position, velocity, density, and \( C_B \) values. These simulations model the case of two satellites in the same initial orbit (likely if they shared a launch vehicle), with a 2000-km initial separation between them. The Runge-Kutta fourth-order integration algorithm is used to calculate the position and velocity vectors after one-second time steps based on the initial conditions. When this integration scheme was utilized to model a circular orbit with \( r = 6978 \) km and only two-body gravitational perturbations, the integration error in satellite position was never greater than 1 m compared to expected analytical values. It was found that due to the periodic properties of unperturbed conic section motion, integration errors cancel out over the course of an orbit. For this particular simulation, we use a model of two

**Figure 4.** 1.5U CubeSat with deployed panels (dimensions in cm).

**Figure 5.** Satellite altitudes over time for 1000, 500, 250, 100, 50, and 25 km distance closure maneuvers.
For the maximum drag configuration:

\[
C_{B_{\text{max}}} = \frac{C_d A_1}{2m_s} = \frac{2.2(0.045\text{m}^2)}{2(1.5\text{kg})} = 0.033 \frac{\text{m}^2}{\text{kg}}
\]  

For the minimum drag configuration:

\[
C_{B_{\text{min}}} = \frac{C_d A_1}{2m_s} = \frac{2.2(0.01\text{m}^2)}{2(1.5\text{kg})} = 0.0073 \frac{\text{m}^2}{\text{kg}}
\]  

As shown by the \(C_B\) values, for a given density and velocity, a satellite in maximum drag configuration will have approximately 4.5 times the drag of a satellite in minimum drag configuration. The control algorithm for inducing a decrease in separation between the two satellites is as follows:

1. The \(C_B\) of the leading satellite is changed to its minimum value, and the \(C_B\) of the chasing satellite is changed to its maximum value. This causes the chasing satellite to fall faster than the leading satellite, allowing it to catch up to the leading satellite.

**Table 1. Properties of Several Distance Closure Maneuvers at Altitude = 600 km**

<table>
<thead>
<tr>
<th>Desired Distance Closed (km)</th>
<th>Time Required (days)</th>
<th>Total Altitude Loss (meters)</th>
<th>Max Altitude Difference ((\delta)) (meters)</th>
<th>Estimated Closure (km) Based on Average (\delta) and Eq. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>32.697</td>
<td>686.191</td>
<td>436.456</td>
<td>1001.603</td>
</tr>
<tr>
<td>500</td>
<td>22.975</td>
<td>485.868</td>
<td>309.891</td>
<td>499.703</td>
</tr>
<tr>
<td>250</td>
<td>16.146</td>
<td>342.935</td>
<td>217.842</td>
<td>246.862</td>
</tr>
<tr>
<td>100</td>
<td>10.417</td>
<td>216.482</td>
<td>137.637</td>
<td>100.629</td>
</tr>
<tr>
<td>50</td>
<td>7.350</td>
<td>153.014</td>
<td>97.383</td>
<td>50.236</td>
</tr>
<tr>
<td>25</td>
<td>5.208</td>
<td>108.309</td>
<td>69.207</td>
<td>25.297</td>
</tr>
<tr>
<td>10</td>
<td>3.299</td>
<td>68.729</td>
<td>43.302</td>
<td>10.035</td>
</tr>
</tbody>
</table>

1.5 kg, 1.5 U (10 cm x 10 cm x 15 cm) CubeSats, each with two 10 cm x 15 cm single deployed long-edge type solar panel arrays and \(C_d = 2.2\), as shown in Figure 4.

For the purposes of this model, the satellites have two possible orientations: maximum drag and minimum drag. For the maximum drag configuration:
2. When half of the desired distance has been closed, the satellite orientations are swapped. The leading satellite is set to its maximum $C_B$ value, while the chasing satellite is set to its minimum $C_B$ value. This causes the leading satellite to lose altitude more quickly than the chaser, bringing it closer to the altitude of the chasing satellite.

3. When the change in satellite angular separation over time ($\frac{d\theta}{dt}$) equals zero (satellites at the same altitude), both satellites are set to the same minimum value of $C_B$. If density is assumed to be roughly constant (because altitude changes are generally small), the behaviors of the satellites before and after the swap will be roughly symmetric, and the satellites will arrive at equal altitudes as the desired distance closure is achieved.

Results

Figure 5 shows the altitude of each satellite over the course of distance closure maneuvers of 1000, 500, 250, 100, 50, and 25 km. The red and black dots indicate the points at which the drag configurations of the satellites are swapped. Each green dot represents the completion of a maneuver (the satellites end up at the same final altitude so that $\frac{d\theta}{dt} \neq 0$). During each maneuver, the black line is always seen below the red line because the chasing satellite must be at a lower altitude if it is to catch up to the leading satellite. A maneuver to increase satellite separation by a given amount would result in the red and black lines trading places (assuming same initial orbital conditions). The slopes of the lines and the times required would be identical to those shown in Figure 5 for the distance closure algorithms.

Figure 6 shows the separation distance between the satellites over the course of the aforementioned distance closure maneuvers. The distance between the two satellites, $s$, is found based on $r_{avg} \Delta \theta$, and the identity

$$ s = r_{avg}(\Delta \theta) $$

where $r_{avg}$ is the average distance between the satellites and the center of Earth. The end of each maneuver in Figure 6 corresponds to the green dots on Figure 5. As evidenced by the zero slope of the graph in Figure 6 at these points, the satellites would maintain a roughly constant separation over time at the end of each control algorithm if a new control algorithm were not promptly initiated. The black dots on the graph (inflection points) represent the points at which the drag configurations of the satellites are swapped.

Table 1 displays the information graphed in Figures 5 and 6, showing the specific numerical values associated with each control algorithm. The average altitude difference ($\delta_{avg}$) and the equation

$$ \Delta \theta = \sqrt{\mu \left( \frac{-3\delta_{avg}}{2r^{5/2}} \right) \Delta t} \quad (4) $$

were used to calculate the $\Delta \theta$ that would result from satellites in circular orbits with an altitude difference $\delta_{avg}$. $s$ values were calculated based on $\Delta$, $r$, and Equation 15 and tabulated for comparison with the data obtained by the numerical integrator. As shown by the table, the values from this equation differed from the integrator values by generally less than 2%, showing that the assumptions made in the derivation of Equation 4 were reasonable, and that the integrator was providing precise and expected values.

Discussion

Fleet Control

The above results show that aerodynamic forces can be effective in controlling satellite orbits. Perhaps the greatest benefit of this method is that it enables satellites to fly in controlled formations without the need for thrusters. The distribution of many small, low cost satellites throughout an orbital plane is now possible, enabling a resolution through time. When one satellite is unable to view an area, the next satellite advances to a position where it can view that area. Since maneuvers that rely on aerodynamic forces take a long time (at high altitude at least), it would be feasible to issue, entirely from the ground, the drag configuration and time-until-swap commands necessary for maneuvers. Satellite control schemes could be updated from the ground as necessary based on satellite position observations provided by NORAD (North American Aerospace Defense Command) and augmented by Doppler-shift data. This method would greatly simplify fleet-based missions, allowing them to succeed
without requiring inter-satellite communication or the use of advanced and expensive onboard position determination and control systems. This simplification would enable universities and other less advanced groups to launch and control fleets of satellites.

It is important to note that the average change in angular separation over time is greater if the average altitude separation is greater. Thus it is more efficient to wait until the desired separation change is as large as possible before initiating a maneuver. The times required ($t_1$ and $t_2$) for two different separation maneuvers (distances $x1$ and $x2$) under identical initial orbital conditions are given by

$$t_2 = t_1 \sqrt{\frac{x_2}{x_1}} \quad (16)$$

**Orbital Decay**

Because a satellite will spend equal amounts of time in minimum and maximum drag configurations during any maneuver, the rate of orbital decay during a maneuver will be about 1.2 times the rate of decay under average mission conditions (tumbling with respect to the velocity vector). If each face is estimated to spend an equal amount of time facing forward in a tumbling scenario, the average surface area perpendicular to velocity would be .023 m², as opposed to .0275 m², during a maneuver. Since maneuvering will likely occur during approximately 10% or less of a mission’s lifetime, these maneuvers will not appreciably increase orbital decay. If specific orientations are not required for the mission at hand, both satellites could be oriented in min-drag configuration if a longer orbit lifetime is desired or in max-drag configuration if a faster de-orbit is desired. A satellite in max-drag configuration would experience about 4.5 times the aerodynamic drag of a satellite in min-drag configuration and would de-orbit 4.5 times faster.

**Future Work**

Current simulations clearly demonstrate the feasibility of aerodynamically based orbit control. However, there are several ways in which the accuracy, breadth, and utility of these simulations can be improved.

Currently, 1976 standard atmospheric density values are used, but real density values can vary by up to two orders of magnitude at any given altitude based on solar and geomagnetic activity. Future simulations will take this into account through the use of more comprehensive atmospheric models like NRLMSISE-00 or JB2008. The estimation of satellite drag coefficients will also be improved, and the control algorithm will be updated to handle the general case of elliptical orbits rather than solely circular orbits. A numerical integration scheme with a variable time step will also be implemented to improve accuracy and reduce simulation run times.

**Acknowledgments**

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References


CONSTRUCTION AND TESTING OF A 
COLTRIMS APPARATUS 
FOR PAIR PRODUCTION BY ELECTRON IMPACT

James Sartor, Marco Keiling, Mike Fogle, & Allen Landers

Abstract

One of the least studied dissociation pathways of a neutral molecule is the decay to an ion/anion pair, yet these reactions can provide new insight into fundamental molecular dynamics. We have constructed a new Cold Target Recoil Ion Momentum Spectroscopy, or ColTRIMS, apparatus in order to study these reactions. We initiate these reactions with the pulsed field from a fast electron, where in principle all ion/anion pair-production modes are accessible and not limited by photo-absorption selection rules. We accomplish this by intersecting a bunched electron beam with a jet of gas over a wide range of electron energies and use a fast-switched electric field to guide the ion products towards two position-sensitive detectors. The positions and flight times of the ions can be used to determine the final state momenta. This data allows the apparatus to be capable of discriminating the reaction channel from dominant contaminant reactions (particularly the electron-producing ionization channels) and determining the kinetic energy release and product angular distribution. In this paper, we discuss the construction of the apparatus, simulation of the apparatus, and preliminary results from the following reaction: \( e^- + O_2 \rightarrow e^- + O^+ + O^- \).

Introduction

Pair production is the process where a molecule, upon impact with a photon (\( \gamma \)) or electron (\( e^- \)), dissociates into two oppositely charged ions. This process can be expressed as either:

\[
AB + \gamma \rightarrow A^+ + B^- \quad (1a)
\]

Or:

\[
AB + e^- \rightarrow A^+ + B^- + e^- \quad (1b)
\]

In general, this phenomenon has not been extensively studied, because both positive and negative ions must be measured in coincidence to confirm that a pair production event has occurred. Nandi, Prabhudesai, and Krishnakumar (2006) observed negative ion production at energies too high for attachment to occur (Figure 1), and although positive ions were not measured, conservation of charge suggests that pair production occurred.

![Figure 1. O^- production as a function of electron energy. The total amount of negative ions produced by electron impact as a function of electron energies is shown. Positive ions were not measured (Reproduced from Figure 7 of Nandi, Prabhudesai, & Krishnakumar, 2006).](image.png)
In order to study pair production, we constructed a new Cold Target Recoil Ion Momentum Spectroscopy, or CotTRIMS, apparatus. CotTRIMS refers to the way data are collected (Dörner et al., 2000). We create a supersonic gas jet by expanding the molecular target gas through a small nozzle, and then we intersect the gas jet with a beam of electrons. There is a finite probability that collisions between the electrons and the target gas molecules will create some ions. An electric field is then generated to separate ions towards two position-sensitive detectors, and based on the time of flight and position on the detectors, we calculate the initial (immediately after dissociation) momentum of the ions. By assuming that the ions are emitted directly along the axis of the molecule, the so-called axial-recoil approximation, we are able to use the calculated initial momentum to determine the initial orientation of the molecule. Based on the relative orientation of the molecules to the electron beam, we can calculate the probability of dissociation with respect to the incident angle of the electron. The probability of dissociation as a function of relative orientation is called the angular distribution.

Using the axial recoil approximation, along with other assumptions such as conservation of energy, charge, and momentum, all the information about one ion can be calculated from the other. However, if both the positive and negative ions can be measured, the signal-to-noise ratio can be greatly increased because a random event occurring close to where a positive ion is expected is unlikely to coincide with a random event occurring close to where a negative ion is expected. For this reason, we have employed a two-detector design for our apparatus.

**Apparatus**

The apparatus, shown in Figure 2, consists of three isolated regions: the jet, the chamber, and the catcher. Each is maintained at about 10⁻⁹ Torr by turbomolecular pumps backed by rotary vane pumps. The jet region prevents excess gas from the gas jet from leaking into the chamber, and the catcher region sits above the interaction region (where the gas jet meets the electron beam) and disposes of excess gas that passes through the interaction region. The purpose of these regions is to minimize contamination in the chamber region. The chamber region contains the electron gun, the spectrometer, and the detectors. Other efforts to keep the chamber region free of contamination include “baking” the chamber (heating it to ~100 °F), which removes water from the chamber walls, and using a liquid nitrogen trap, which causes free water molecules in the chamber to condense onto the trap.

In the drawing of the apparatus, shown in Figure 3, only the chamber region is shown. The experiment is carried out in the following manner. A supersonic gas jet is created by allowing a pressurized gas to escape through a 10 μm aperture. The gas undergoes adiabatic expansion due to the high vacuum in the chamber. The
expansion leads to a cooling of the jet to about 15 K (Murphy & Miller, 1984), and the cooling ensures that the gas specimen is in its lowest vibrational and rotational energy states, although it has a high velocity (corresponding to translational energy). The benefits of using a gas jet rather than a diffuse target are that it is easy to ensure that it is thermally cold and that the beam is localized. The diameter of the gas jet at the interaction region is about 2 mm, and the density of the molecules is on the order of 10^{12} \text{cm}^{-3}.

The gas jet is then intersected with a pulsed beam of electrons, formed via a Kimball Physics ELG-2 electron gun. The energy of the electrons can easily be adjusted by changing the electric field that accelerates the electrons before they leave the gun. A set of Helmholtz coils creates a magnetic field that is coaxial to the electron beam. The magnetic field confines the beam, in that any electron velocity in a direction other than the beam axis is transformed into a helical motion around the beam due to the Lorentz force. Beam confinement is especially necessary for low energy electrons which are more prone to spreading from electrical repulsion. The electrons are collected in a Faraday cup directly behind the interaction region, allowing for measurement of the electron current and optimizing the transmission through the apparatus. Because the electron gun, interaction region, and Faraday cup are collinear, the current through the interaction region is maximized by maximizing the current in the Faraday cup.

After a short delay (100-500 ns after the end of the electron pulse), a grid on the positive side of the spectrometer is pulsed to a negative voltage. The voltage creates an electric field that "pushes" any negative ions away from it and "pulls" positive ions towards it. The grids are necessary to create "flat" electric fields (electric fields with straight field lines rather than curved, as in a lens) while still allowing particles to pass through. The pulse length is calculated using a simulation to be shorter than the time it takes for an ion to leave the interaction region. As long as the pulse length is shorter than the time for an ion to leave the region, each ion (of the same species) receives the same impulse (J), as shown below:

\[ J = \int F \cdot dt \] (2a)

\[ \Delta p = \int E \cdot q \, dt \] (2b)

\[ \Delta p = E \cdot q \cdot (\text{pulse width}) \] (2d)

\[ \Delta (mv) = E \cdot q \cdot (\text{pulse width}) \] (2e)

\[ \Delta v = \frac{E \cdot q \cdot (\text{pulse width})}{m} \] (2f)

where \( F \) is force, \( E \) is electric field, \( t \) is time, \( q \) is charge, \( p \) is momentum, \( m \) is mass, and \( v \) is velocity.

Therefore, every ion with the same charge-to-mass ratio receives the same change in velocity towards the detector. After this initial pulse, the ions travel through two tubes with no electric field, called the drift region, which allows them to spread out spatially and temporally. A longer drift region generally leads to higher resolution. This whole cycle can happen at a rate of a few kHz, before events from one cycle start to bleed into the next.

At the end of each drift region is an ion detector. It consists of a microchannel plate stack (MCP) with a delay-line anode. The MCP is held at a high voltage and is made of a material with a very low work function. When the MCP is hit with an ion, a cascade of electrons is released. The cascade is seen electronically as a voltage spike. The electrons then go on to hit the anode, which consists of two sets of wire wrappings: one vertical and one horizontal. These collisions are also detected as a voltage spike. The amount of time it takes for the signal to reach one end of the wire is proportional to the position of the electrons on the anode in that dimension. Signal noise is then filtered out with electronics (discriminators, noise filters, etc.), and the remaining signals are converted into digital signals, and delivered to the computer for analysis.

**Simulation**

We used an Excel spreadsheet to calculate approximate times of flight for a given pulsing system and ion produced. A function in the spreadsheet integrates iteratively over velocity through the impulse equation
shown above and calculates the time of flight and spread on the ion detector. The ion’s energy, charge, and mass can be varied, along with spectrometer dimensions and pulse height, length, shape, and delay time between the electron pulse and spectrometer pulse. Results of the simulation are shown in Figure 4.

**Experimental Setup**

Once the ColTRIMS apparatus was constructed, we began to collect data. We first tested the apparatus with an argon target to ensure that the electron beam was intersecting the gas jet. The test uses single ionization of argon, which has a much higher cross section than any pair production event. Testing with argon gives much cleaner data relative to the background noise. An image of the detector is shown in Figure 5. Note the stripe of ionized gas across the center of the detector and the raised argon jet dot due to the vertical jet velocity sending ions born in the jet higher on the detector. To test the target molecule, we set the electron beam to 32.8 eV and replaced the argon in the jet with oxygen. We also experimented with other electron energies, but the 32.8 eV run provided the best data due to the higher cross section at that energy (Figure 1).

Since the cross section is known, we can estimate the rate at which we expect the reaction to occur. The rate is given by the product of the following:

- The number of electrons per cycle: 10 nA (measured on the Faraday cup) converted from Amperes to electrons/second
- The number of oxygen molecules per electron: the jet density times the intersection volume (volume of a bicylinder = $16/3 \cdot \pi \cdot \text{radius cubed}$) divided by the cross sectional area of the electron beam times the approximate cross section of the interaction (Itikawa, Ichimura, Onda, Sakimoto, & Takayanagi, 1989)
- The cycle rate, 6 kHz

These parameters give an expected rate of 2.225 Hz (Equation 3).

\[
\frac{10 \text{ nA}}{1.602 \times 10^{-19} \text{C}} \cdot 100 \text{ ns} \cdot 10^{12} \text{ cm}^{-3} \cdot \frac{16}{3} \cdot \frac{(1 \text{ mm})^3}{\pi (1 \text{ mm})^2} \cdot 0.35 \cdot 10^{-18} \text{cm}^2 \cdot 6 \text{ kHz} = 2.225 \text{ Hz}
\]

Figure 4. Example of spreadsheet simulation. Green and purple ellipses represent bunches of negative ions of different mass or charge (in this case, O$_2^-$ and O$^-$.); red and blue ellipses represent bunches of positive ions of different mass or charge (in this case, O$_2^+$ and O$^+$.). The horizontal axis shows time (absolute value) that ions arrive at the detector; vertical axis shows ion position in the x direction. The bunches are modeled as starting at the center of the interaction region with the same energy (velocity) in all possible directions.

Figure 5. Argon jet test (positive ions). The electron beam travels across the x direction and the gas jet travels upwards. The jet dot (raised because of the jet momentum) can clearly be seen above the hot gas stripe, a result of random gas in the chamber being ionized by the electron beam.

We expect about two pair production events to occur per second.

Each ion must pass through two grids to reach its detector. Each grid has an efficiency of about 90%, so the probability of an ion reaching the detector is $(0.9)^2 = 0.81$. The probability of a pair of ions both reaching their detectors is then $(0.81)^2 = 0.6561$. 

Equation 1:

\[
\text{AB} + \gamma \rightarrow \text{A}^+ + \text{B}^- \quad (1a)
\]

Or:

\[
\text{AB} + e^- \rightarrow \text{A}^+ + \text{B}^- + e^-. \quad (1b)
\]

Equation 2:

\[
\begin{align*}
J &= F \cdot d \cdot d \\
J &= E \cdot q \cdot d \\
\Delta p &= E \cdot q \cdot (p \cdot \omega) \\
\Delta m &= E \cdot q \cdot (p \cdot \omega) \\
\Delta v &= ! \cdot ! \cdot ! \cdot (! \cdot 100 \text{ ns} \cdot 10^{-18} \text{cm}^2 \cdot 6 \text{ kHz}
\end{align*}
\]

Equation 3:

\[
\frac{10 \text{ nA}}{1.602 \times 10^{-19} \text{C}} \cdot 100 \text{ ns} \cdot 10^{12} \text{ cm}^{-3} \cdot \frac{16}{3} \cdot \frac{(1 \text{ mm})^3}{\pi (1 \text{ mm})^2} \cdot 0.35 \cdot 10^{-18} \text{cm}^2 \cdot 6 \text{ kHz} = 2.225 \text{ Hz}
\]
Therefore only about 66% of pair production events are detected on both detectors.

As a result, we expect to observe \((0.6561 \cdot 2.225) = 1.4598225\) pair production events per second.

**Results of Preliminary Tests**

We observe peaks in the positive time of flight spectrum where \(O^+\) was predicted by the simulation, and in the negative time of flight spectrum, where \(O^-\) was predicted. When we plot them against each other (Figure 6), we found a correlation slope of approximately 2.59, which very accurately matches the ratio of distances to the detectors (2.6). This matching strongly suggests that pair production has occurred because a positive and negative ion formed from pair production will have exactly the same velocity in opposite directions, and the pulse from the field will add the same amount of velocity to each of the ions (Equation 2f).

Unfortunately, due to a systematic error in the position measurements, we did not obtain enough significant differential data to orient the molecule and obtain angular distributions.

**Conclusion**

We have successfully designed and constructed a new apparatus for studying electron impact pair production. We have also demonstrated the functionality of the apparatus by measuring pair production events in \(O_2\). Future modifications to the apparatus will include an addition of a “second stage” vacuum region between the jet and chamber regions in order to reduce the amount of background gas in the chamber region. This apparatus will be used in the future to study pair production channels in other molecules, such as \(H_2\) and \(CF_4\), as well as other ion producing phenomena, such as the asymmetry in the ionization of \(HD\).

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**References**


In 1987 the National Science Foundation established the Research Experiences for Undergraduates (REU) program, which funds summer undergraduate research positions all over the United States. The main purpose of this initiative has been to give undergraduate students the opportunity to work closely with faculty and peers on scientific research projects. If accepted into a REU, the student is given a stipend for the summer’s work, usually lasting 10 weeks. There may also be compensation for travel costs and food and lodging. The student is treated like a paid, professional researcher, similar to a graduate school experience. An REU is an excellent way for undergraduates to gain a realistic and immersive research experience as they consider their future career path and hone the skills needed to succeed in both academia and the workforce.

Auburn University currently offers five REUs in the areas of Aquatic Ecology, Biosystems, Computer Science and Software Engineering, Mathematics, and Micro- and Nano-materials. Each of these REU programs provides students with an introduction to the research in that area, teaches experimental design and methods for collecting data, and provides the student with a mentor to supervise their individual projects. These diverse and rigorous REU programs are open to both Auburn students and students from other institutions.

The best way for a student to become aware of research opportunities available to them is through faculty encouragement. For instance, James Kaczmarek, a recent Auburn graduate now attending graduate school at Massachusetts Institute of Technology, participated in the Micro- and Nano-materials REU and was alerted to the program by his professor. The actual application process for an REU can vary in its requirements, but nevertheless prepares a student for future solicitations. The specific logistics of a program differ depending on the REU, but they are all designed to equip a student with necessary skills to move onto the next step in their education and career path.

Likewise, most REU’s include structures that help students develop professionally. For example, the Biosystems REU at Auburn includes professional development seminars to help students learn how to write scientifically and how to gather information. In the Micro- and Nano-materials REU, Kaczmarek participated in its biweekly meetings with the other REU students for professional development seminars and research presentations from “the cohort.” Furthermore, twice during the summer, he presented his work to his peers and mentors. The Smart UAV’s REU has a standard of biweekly meetings. By the end of the program, the student will have completed two presentations, two reports, and one publishable paper (Samuel Ginn College of Engineering, 2013b). The Aquatic REU includes a fieldwork component for the students’ individual projects in some of the biologically diverse surrounding waterways including ponds, rivers, streams, reservoirs, estuaries, and wetlands (Wilson, 2013). In his REU, Kaczmarek presented a poster at a competitive gala judged by members of the Auburn community, which helped to prepare him to present at regional and national level conferences (Samuel Ginn College of Engineering, 2012). The Biosystems REU also concluded with a poster session hosted by the program. There the students presented to peers, graduate students, and mentors. They were also able to invite family and friends to the presentation (Gupta, 2013; Samuel Ginn College of Engineering, 2013a).
An excellent example of how an REU and the relationships it forms can be immediately launch more opportunities comes from another Auburn student. Adam Blumenthal, a senior in Mathematics, participated in the Mathematics REU and, from his work there he wrote a mathematical proof that has now been accepted to the International Journal of Mathematics and Computer Science. Moreover, because of his REU experience Blumenthal was able to travel to South Africa with his mentors, Dr. Pete Johnson and Dr. Overtoun Jenda, to help establish an international community in mathematics. This experience led him to a professional collaboration with a University of Cape Town professor and another project on its way to publication.

Research Experiences for Undergraduates are an excellent way for undergraduates to figure out where their interests truly lie and create a solid foundation from which future work and collaborations can grow. Adam Blumenthal changed his career path after his REU. Originally, he was planning to attend graduate school for algebra theory, but during the REU, he found himself more attracted to the graph theory problems. The Mathematics REU gave him the chance to discover whether or not he wanted to continue into graduate school and the research track beyond. James Kaczmarek continues to have a professional relationship with his former mentors, Dr. Mark Bryne and Dr. Steve Duke, and strives to follow their professional examples. As Kaczmarek notes, his REU experience “showed me that research was a path I wanted to pursue.” He also credits the REU as a critical determinant in his acceptance to the Massachusetts Institute of Technology. An REU is no small experience; it has the potential to radically impact an undergraduate student’s professional future.

Students considering a research-intensive career will benefit from the REU experience. Few opportunities give undergraduates a more realistic taste of a given research profession and insight into whether they will enjoy the professional life of a researcher. Moreover, the student gains professional skills and makes meaningful bonds with peers and faculty. As with Kaczmarek and Blumenthal, the REU could inspire a life-changing career decision.

References


Gabby Bates is a recent Auburn graduate with a B.A. in Creative Writing and a minor in Spanish. At Auburn, she worked as a lead consultant at the Miller Writing Center and served as managing editor for The Auburn Circle. With the help of an undergraduate research fellowship, she mapped and analyzed common structures among three of the most enduring works of literary journalism ever published and wrote a rhetorical analysis to display how “enactment” functions in each piece. Her creative work has been published or is forthcoming in Broadsided, Redactions, B-metro, and Southern Humanities Review. In the fall, she hopes to pursue a M.F.A in Creative Writing with a concentration in Poetry.

Sanny Omar became involved in research through his membership in the Auburn University Student Space Program. He began researching novel methods of satellite fleet control and ended up designing the AubieSat satellite mission called C3D2 (CubeSat Constellation Control by Differential Drag). Sanny received an honorable mention award in the international Frank J. Redd student Scholarship Competition after presenting his research at the 27th annual AIAA/USU Conference on Small Satellites. Sanny also holds a private pilot license with an instrument rating, is a certified scuba diver, and holds a ham radio technician license. He plans to pursue a Ph.D. in space engineering and work to design the aircraft and spacecraft of tomorrow.

Trenton Fisher is a senior pursuing a degree in Communication with a minor in History. He walked-on Auburn’s football team in 2010 and redshirted during his first year for the Tigers. In his second year, he played in the first eight games before a season-ending ankle injury at LSU. Trent earned a scholarship in August prior to the 2012-2013 season, where he played safety and on special teams. He played in every game in 2013-2014, helping Auburn earn its second SEC title in four years and an appearance in the BCS National Championship Game in Pasadena. Trent is currently interning for ESPN and will graduate in May.
**Kodye Abbott** is a recent graduate in Molecular Biology, College of Science and Mathematics. Kodye became interested in research during his sophomore year while working as an undergraduate researcher in a molecular genetics lab at the Auburn University College of Veterinary Medicine (AUCVM). The exposure to chemotherapy resistance studies lead by Dr. Satya Pondugula piqued an interest that influenced him to become involved with multiple projects that focus on chemoresistance and the mechanisms involved in the development of chemoresistance. Kodye is currently employed as a research assistant at the AUCVM and plans to pursue his masters in the field of Biomedical Sciences.

**James Sartor** initially became interested in physics research during his sophomore year at Auburn. His current research explores the dynamics of molecular systems, both in Auburn and at the Advanced Light Source at Lawrence Berkeley National Laboratory. After graduating in December 2013, he plans to continue with research and pursue a Ph. D in physics.

**Maria Hines** is a student in the Landscape Architecture program at Auburn University. Her interest in landscape architecture developed from passions in art, urban environments, and exploring local ecologies. While at Auburn, Maria has worked with Professor Charlene LeBleu on projects ranging from stream restoration and low impact development and BMP design proposals to presenting research at academic conferences. She is interested in multi-disciplinary design and ecological strategies which treat landscape as a medium for urban design transformation. Upon completion of her master’s degrees in Landscape Architecture and Community Planning, she would like to become a registered landscape architect at a multi-disciplinary design firm.