



ASTRA

The McNair Scholars' Journal

2023

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University of Wisconsin-Eau Claire

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The Ronald E. McNair Postbaccalaureate
Achievement Program is a Federal TRIO
Program,
funded by the U.S. Department of
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Editorial Assistance by Claire Bradley, Max
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Original Cover Design by Taylor Qualey



**Message from Provost and Vice Chancellor
Patricia A. Kleine**

I am writing this as the snow outside is softly coating the budding trees, submerging the emerging grass, and shaking the daffodils bravely trying to show their spring colors. It is 3:00 p.m. on April 17. Thankfully, the nearly 3,600 undergraduate researchers and their mentors (from 45 states and 6 countries) have left the campus having just spent three exhilarating days exploring creative works, scientific discoveries, and humanistic projects at the National Conference for Undergraduate Research (NCUR) in Eau Claire. Among these emerging “discoverers and innovators” were many McNair Scholars, including a healthy contingent from UW-Eau Claire, presenting their work over the course of their time as a scholar and making plans to attend the graduate schools of their choice or taking an “academic gap year” (as one student told me) to work in a national research laboratory. Dr. Ronald E. McNair would be proud of their efforts given his name is affixed to the preeminent undergraduate program for young, multicultural scholars in the country.

I personally moderated three oral sessions comprised of McNair Scholars and other undergraduate researchers from prestigious institutions. The caliber of presentations exceeded even my expectations. And UW-Eau Claire McNair Scholars stood shoulder-to-shoulder with the best of them. I was proud.

Since 1988, UW-Eau Claire has had a long-standing commitment to excellence in undergraduate student/faculty research as evidenced by the 2016 NCUR national award for undergraduate research accomplishments. No program exemplifies the institution’s commitment to opportunities in undergraduate research for students more than the UW-Eau Claire Ronald E. McNair Post-Baccalaureate Achievement Program. This journal reflects the culmination of two years of McNair students working with their faculty mentors on critical questions in their disciplines and preparing their research for presentation at professional conferences and publication in professional journals.

I want to congratulate the students on the completion of their research projects and the faculty mentors on their steadfast commitment to ensuring the students’ success in their research. I know the hours spent in the labs, classrooms, field sites, or performance spaces have been enriching for both faculty mentors and their McNair Scholar. I hope all of you enjoy reviewing this journal and the wealth and breadth of the research presented within it.

Regards,

Patricia A. Kleine

Provost and Vice Chancellor for Academic Affairs

Academic Year 2022-2023

McNair Scholars' Faculty Mentors

- Dr. Saori Braun, Kinesiology
- Dr. Bart Dahl, Chemistry and Biochemistry
- Dr. Jon Heggstad, English
- Dr. Krysti Knoche Gupta, Chemistry and Biochemistry
- Dr. Damir Kovačević, Political Science
- Dr. Mary Beth Leibham, Psychology
- Dr. Nicole Schultz, Communication and Journalism
- Dr. Michael Walsh, Materials Science and Biomedical Engineering
- Dr. Kelly Wonder, McNair Program

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Assisting Identity Construction Through Coming-of-Age Films

Shantel Brown
Dr. Jon Heggstad

Abstract

This paper aims to combine developmental psychology with cinematic theory to raise awareness of how coming-of-age films could assist adolescents and emerging adults in identity development. To do so, I will draw upon the work of psychologists Erik Erikson and Jeffery Arnett, exploring the characteristics that distinguish identity development in adolescents and emerging adults. I will then juxtapose these characteristics with Dr. Vittorio Gallese and Dr. Michele Guerra's research in neurocinema to explore how films can support identity development, especially those centering intersectional identity representation (the female gaze). After parsing these works on child development and neurocinema, I offer a series of case studies of modern coming-of-age films from the last decade, detailing whether those narratives reinforce the female gaze and how they do so. I will conclude this paper by raising awareness of the importance of conscious consumerism and intentional exposure to increase the production and distribution of intersectionally diverse films.

Literature Review

Establishing a sense of identity is a fundamental milestone for most adolescents and emerging adults. It is an inevitable part of typical human development. According to Erik Erikson, a 20th-century psychoanalyst, identity construction during adolescence consists of conflict between identity achievement and identity confusion, or what Erikson additionally refers to as the identity vs. confusion stage of psychosocial development. During this stage of development, adolescents experiment with various identities. These identities are critiqued or affirmed by those who surround the adolescent. The adolescent then uses this feedback while factoring in their morals and goals to either adopt or reject the experimental identities. Successful resolution of this stage is achieved when an adolescent identifies and embodies an identity that compromises their vision of themselves and the expectations of family, peers, and the community. Erikson refers to this as the "sense of inner identity" stage:

The wholeness to be achieved at this stage I have called a sense of inner identity. The young person, in order to experience wholeness, must feel a progressive continuity between that which he has come to be during the long years of childhood and that of which he promises to become in the anticipated future; between that of which he conceives himself to be and that of which he perceives others to see him and to expect

him. (87)

According to Jeffery Jensen Arnett, a Senior Research Scholar at Clark University and author of *Emerging Adulthood: The Winding Road from the Late Teens through the Twenties*, identity exploration is also a critical component of emerging adulthood. Unlike adolescents, Arnett theorizes that the identity development stage for emerging adults centers on solidifying their love and career aspirations:

Perhaps the most crucial feature of emerging adulthood is that it is the time when young people explore possibilities for their lives in a variety of areas, especially love and work. In the course of exploring love and work, emerging adults clarify their identities, that is, they learn more about who they are and what they want out of life. (8)

Arnett emphasizes that this identity exploration is possible due to emerging adults' rising independence. Their growing independence from their parents allows emerging adults to explore their inclinations in love and work (Arnett 8-10). Without looming parental pressure, emerging adults can become more self-focused, taking note of their individual preferences and ambitions. These preferences and ambitions set the foundation for identity development, emphasizing to emerging adults their existence beyond the family unit.

Now that we have explored the experiences associated with identity development for adolescents and emerging adults, I want to explore how technology's role may further support these populations' identity development. I want to preface that no definitive conclusions have been made about technology's impact on identity development. This area of study is contemporary and is in its preliminary phases of investigation and replication: therefore, the content henceforth is primarily exploratory and theoretical.

In the case study "Identity development in the Digital Age: An Erikson Perspective," researchers Dr. Katie Davis and Dr. Emily Weinstein open their study by quoting the following statistics regarding adolescent and emergent adults' technology use: "Among 18- to 29-year-olds, 85% own smartphones and 82% of those who use the internet are social media users," and, "Among a slightly younger group, 92% of 13 to 17-year-olds use the internet on a daily basis, 88% have access to mobile phones, and 76% use social media" (1). These statistics serve to stress adolescent and emerging adults' dependence on technology, the internet, and social media today.

I want to stress that an excess of anything can become problematic; however, if adolescents and emerging adults can use technology, the internet, and social media in moderation, I propose that these mediums can be a tool to assist these populations in their identity formation. For adolescents, access to technology and the internet increases exposure to a more significant number of identities for experimentation, including identities outside their physical family unit and community. This increased exposure could give adolescents the variety necessary to find an identity that best compromises societal acceptance and personal morals and ambitions. Furthermore, social media can serve as a setting for adolescents to embody identities to gain further feedback regarding their experimentation. I urge readers to consider that the additional identities and the additional space for experimentation could catalyze the number of successful resolutions of Erikson's identity vs. confusion stage of psychosocial development.

On the other hand, access to technology and the internet could give emerging adults the illusion of independence at an early age. Similarly, emerging adults could use the internet as an

additional place to experiment with love and work. Social media and dating networks increase an emerging adult's ability to explore intimacy preferences. Furthermore, the internet and social media could also serve as a place of work, allowing emerging adults to develop and distribute content and creations anywhere, anytime. This increase in love and work experience could assist emerging adults in determining their life preferences and ambitions, which is, again, the foundation of their identity development.

If, theoretically, technology, the internet, and social media can support identity formation, I pushed myself further to question what other technology-dependent mediums could potentially assist identity development. This led to the consideration of film.

A film has the ability to transport a viewer, providing them with the sensation of being transported to an alternate reality. This sensation largely derives from the brain's response to a film's movement. The parts of the brain that are responsible for processing movement and social interactions are *also* engaged when watching a motion picture. Professors Vittorio Gallese and Michele Guerra raise awareness of this in their book *The Empathetic Screen*. In *The Empathetic Screen*, Dr. Gallese and Dr. Guerra provide a neurological framework for understanding what happens in the human brain when viewing a film:

When we watch a movie, not only do we focus our attention exclusively on the screen, but our immobility releases all our resources of embodied simulation and uses them to create an absorbing relationship with the characters of the plot. (43)

Dr. Gallese and Dr. Guerra argue that this "absorbing relationship" between a protagonist and the audience is a direct response to a film's cinematography. Dr. Gallese and Dr. Guerra explain this feeling is onset from a movie's composition:

Movement, action, interaction, gestures, sentiments and emotions, which unfold in a bi-dimensional space that gives the illusion of being three-dimensional and in which we feel we know our way around, even to move around. Our brain-body system not only gives us experience of that virtual space and allows us to process a spatial cognition that we need to live a given experience, it also puts us in a position to share the situation, actions, gestures, and emotions that take place in the other dimension represented on the cinema screen. (44-45)

Through the cinematic experience, adolescents and emerging adults get the sensation of navigating the fictional world with the film's protagonist. Similar to social media, I propose that cinema can function as another space for identity exploration. In a film, the protagonist's identity is a point of further identity experimentation. Adolescents can note how society and the protagonist's family react to the character's identity, which acts as a substitute for their real-world identity exploration *or* providing an additional identity available for experimentation. On the other hand, emerging adults can use the protagonist's experience navigating love quarrels and/or work-related hardships to aid in the construction of their intimacy and career drive.

Another critical aspect that Dr. Gallese and Dr. Guerra highlight in the quote above is the viewer's ability to empathize with the protagonist's fictional situation, experiencing the protagonist's emotions as if they were the viewer's own. Dr. Gallese and Dr. Guerra attribute this sensation to the film's ability to stimulate the cerebral brain regions that are activated in daily living:

The emotions and feelings experienced by others, independently of whether they are

real or not, are first of all constituted and directly understood through a reusing part of the same neural circuits on which our first-hand experience of these same emotions and feelings are based. (38)

In tandem with physically feeling as if they were navigating the fictional world with the protagonist, the viewer, consequently, gets to endure the character's emotional burdens. For example, if a protagonist is ostracized from their family due to their sexuality, an adolescent viewer could also experience the character's sense of isolation. If a protagonist becomes infatuated with the neighbor next door, an emerging adult may also fall for that neighbor. If a protagonist completely botches a job interview, an emerging adult may experience that disappointment alongside the character.

Given the information from *The Empathetic Screen*, I cannot help but ponder whether a film could be a surrogate for identity experimentation. Could an adolescent or emerging adult's journey "with" a protagonist be enough for them to embody or reject an identity? In the following sections, I proceed as if the mentioned speculation is hypothetically so: therefore, if adolescents and emerging adults *are* using film as a mode of identity exploration, I aim to explore the types of identities these two populations are being exposed to.

Upon examining common identities in cinema, I often came across Laura Mulvey's concept of the male gaze. In her essay "Visual Pleasures and Narrative Cinema," Laura Mulvey, a British feminist film theorist, explains how classic cinema was aimed to feed a man's scopophilic urges or need for visual pleasure. She explains that heterosexual white men have predominantly run the film industry and, thence, produce films that also target a similar male audience. Mulvey goes on to explain that directors feed into scopophilic urges by recognizing its two drives: "pleasure in using another person as an object of sexual stimulation" and "identification with the image seen on screen" (61). The first form of pleasure plays off man's sexual instinct, his natural/biological urges to reproduce. In contrast, the second form of pleasure satisfies man's ego, being a spectator and finding recognition of what he likes being represented in the outside world. Film directors can satisfy these pleasures by manipulating camera shots to glorify women's physiques.

These findings suggest that a large portion of films are dedicated to objectifying women and centering heterosexual, white male protagonists. In return, a minuscule portion of identities are captured on-screen; thus, I am concerned that the male gaze could thwart identity exploration via film. To increase the number of identities portrayed in cinema, I suggest that a new gaze is needed in the film industry — a *female* gaze. The female gaze I urge for would not subvert the male gaze by flipping the male and female binary but rather spotlight more intersectional identities.

The idea of showcasing intersectional identities stems from the work of civil rights activist and critical race theorist Kimberlé Crenshaw. Over the years, Crenshaw has coined and raised awareness about the topic of intersectionality. According to the definition she shared at the 2020 MAKERS Conference, intersectionality is "the complex, cumulative way in which the effects of multiple forms of discrimination (such as racism, sexism, and classism) combine, overlap, or intersect, especially in the experiences of marginalized individuals or groups" (Crenshaw 02:07). Crenshaw uses the overlapping arrows on her slide to suggest how identities (i.e., race, class, gender, ability, ethnicity, religion, language) can interact together to create

unique sets of experiences.

In my definition of the female gaze, I play into Crenshaw's definition of intersectionality. I argue that the female gaze can be a perspective in which intersectional identity experiences are the center of a film's plot and character development. If a male gaze is narrow, limiting, patriarchal, and domineering, a female gaze should be the opposite of these characteristics, opening a space for characters and viewers to explore. Thus, reducing the prominence of the male gaze and implementing a more representative female gaze increases audience exposure to the experiences, values, and cultures of a multitude of races, classes, genders, abilities, ethnicities, religions, languages, and sexualities. For adolescents, the perspective of the female gaze can potentially increase the number of identities available for experimentation. In addition, the film medium theoretically functions as a space where adolescents can feel the illusion of embodying an identity, thus being able to decide whether to embody or reject a given identity in the real world. For emerging adults, the female gaze and film could work together to provide the sensation of navigating love and work experiences. The display of intersectional identities theoretically allows emerging adults to find a protagonist that best resembles their own set of intersectional experiences. They can then use the protagonist's experiences in the fictional world to help solidify their intimacy preferences and career ambitions.

Again, I want to stress that researchers have yet to determine whether technology impacts adolescent and emerging adults' identity development. The prediction above is pure correlational speculation, given existing research on identity formation, technology usage, and the cinematic experience. I use the above speculation as the focal point of this exploratory research. If film can be a mode and a medium for identity experimentation, then what identities are adolescents and emerging adults being exposed to today? To answer this question, this study sought to perform content analyses of coming-of-age films, examining intersectional identity representation within them. The coming-of-age genre was intentionally chosen given its dependency on an identity exploration narrative and its marketing toward adolescents and emerging adults.

Methodology

I conducted case studies of 5 selected coming-of-age films from the last decade. Films were chosen based on popularity and notability, chosen with the knowledge that they will likely be familiar to a broad audience. In addition, I avoided choosing films released in the same year. This choice was implemented with the intention that choosing films from different years would unveil possible trends in intersectional identity representation.

I annotated these films for intersectional identity representation amongst the leading and supporting characters. Notable annotations were determined through the external appearances of characters, dialogic mentioning of one or more of the six aspects of Crenshaw's intersectionality, and its impact on a given character's experiences and sense of self.

Results

CASE STUDY 1: The Perks of Being a Wallflower (2012). *The Perks of Being a Wallflower* is a coming-of-age film that is based on the Stephen Chobsky novel of the same title. The film

centers around Charlie, a high school freshman who struggles with mental illnesses that stem from the trauma and death of his aunt, Helen. When Charlie starts high school, he meets and befriends two seniors named Sam and Patrick. Sam and Patrick welcome Charlie into their friendship circle, exposing him to new experiences involving music, drugs, and love. Through their friendship, Charlie begins to overcome his symptoms of depression, anxiety, and PTSD, allowing him to enjoy more aspects of life.

Focusing on the protagonist Charlie, the intersectional identities captured in this film include disability and sexuality. Throughout the film, Charlie struggles to manage his symptoms of mental illness. The audience learns that Charlie suffers from depression, anxiety, and PTSD, stemming from the death of his Aunt Helen. At times, Charlie expresses through his monologues being consumed and frustrated by his mental illnesses in his day-to-day life:

CHARLIE. If my Aunt Helen were still here, I could talk to her. And I know she would understand how I am both happy and sad, and I'm still trying to figure out how could that be. (00:08:00 – 00:08:08)

At another points in the film, Charlie discusses his trauma with other characters, such as his sister, Candace:

CHARLIE. Candice, I killed Aunt Helen, didn't I? She died getting my birthday present, so I guess I killed her, right? I tried to stop thinking that, but I can't. She keeps driving away and dying and I can't stop her. Am I crazy, Candace?

CANDICE. [Candace motions to one of her friends] Call the police and send them to my house! [back to the phone] No, Charlie, listen to me. Mom and Dad are going to be home with Chris any second.

CHARLIE. What if I wanted her to die, Candace? (01:30:07 – 01:30:33)

To manage his depression, anxiety, and PTSD symptoms, Charlie can be observed both taking medication and communicating with his therapist. However, despite this support, Charlie's mental illness symptoms still impede his ability to form close relationships. This can be seen in Charlie's relationship with Sam.

Upon meeting Sam and Patrick, Charlie is immediately drawn to Sam's charm and personality. As Sam and Charlie spend more quality time together, their relationship transforms from platonic to romantic. This connection, however, becomes complicated because of Sam's feelings for her ex-boyfriend, Craig, and Charlie's struggles with mental illness. The audience observes the interference of Charlie's mental illness in his and Sam's relationship when the two talk about how Charlie never had the courage to ask Sam out in high school. In this situation, Sam exasperates, "You can't just sit there and put everybody's lives ahead of yours and think that counts as love" (01:25:36 – 01:25:41). Sam finds herself frustrated with Charlie's lack of social skills and confidence, which we, as the audience, know stems from Charlie's social anxiety as a result of his previous trauma.

While Charlie's mental illness creates obstacles in his and Sam's relationship, it does not wholly exclude the two from falling in love with each other. For example, during a secret Santa gift exchange, Sam takes Charlie to her room to share the typewriter she purchased to support his writing career. While there, Sam goes out of her way to reassure Charlie that despite his past experiences, he, too, deserves love. Sam validates this message by sharing her own feelings for Charlie and also sharing his first kiss with him:

SAM. Charlie, I know that you know I like Craig. But I want to forget about that for a minute, okay?"

CHARLIE. Okay.

SAM. I just want to make sure that the first person who kisses you loves you. Okay?

SAM. [Sam and Charlie kiss. Sam pulls away] I love you, Charlie.

CHARLIE. I love you, too (00:46:16 – 00:47:08).

Despite Charlie's battle with mental illness, Charlie and Sam were able to nourish and grow in their relationship. Specifically for Charlie, his love for Sam became the additional support he needed to better manage his symptoms of depression, anxiety, and PTSD.

Because Charlie's mental illness is seen as a point of connection *and* interference in his romantic relationship, the relationship between Charlie's disability and sexuality illustrates how *The Perks of Being a Wallflower* takes an intersectional approach.

CASE STUDY 2: The Fault in Our Stars (2014). *The Fault in Our Stars* is a romantic coming-of-age film based on the John Green novel of the same name. The film captures the love story of two teenage cancer patients, Hazel and Augustus, who meet at a support group and fall in love. Despite their illnesses, the two motivate one another to enjoy the little things in life: traveling, reading, and picnics, thus making the most of the limited time they have together.

Through the characters Hazel Grace and Augustus Waters, the film *The Fault in Our Stars* showcases the intersection between disability and sexuality. The intersection of disability is established at the beginning of the film with Hazel's opening monologue:

HAZEL. I believe we have a choice in this world about how to tell sad stories. On the one hand, you can sugarcoat it the way they do in movies and romance novels, where beautiful people learn beautiful lessons, where nothing is too messed up that can't be fixed with an apology and a Peter Gabriel song. I like that version as much as the next girl, believe me. It's just not the truth. This is the truth. Sorry. (00:00:36 – 00:01:06)

Hazel prepares her audience that this film will tell an authentic love story, a love story that is later revealed to be about two cancer patients: Hazel and Augustus. Hazel is depicted as a teenage girl navigating her adolescent years with stage IV thyroid cancer. She is often seen wheeling around her oxygen tanks, which are needed to support her weakened lungs. On the other hand, Augustus is a teenage male living with osteosarcoma. Due to his cancer, Augustus lost his leg and must maneuver through the world with his prosthetic leg.

Throughout the film, Hazel reflects on her cancer diagnosis, causing her to feel isolated by those around her. To show how her cancer separates her from the "normal teen experience," Hazel shares her daily routine with the viewer, noting, "that was my life. Reality shows. Doctors appointments. Eight prescription drugs, three times a day" (00:05:03 – 00:05:11). She even mentions that not only does her cancer foster isolation, but the knowledge that her cancer may become fatal leads her to also suffer from mental illness. Hazel explains, "The booklets and websites always list depression as a side effect of cancer. Depression's not a side effect of cancer. It's a side effect of dying" (00:01:28 - 00:01:41). Between Hazel's isolation and depression, Hazel's mother suggests that she attend a support group sessions. She encourages Hazel to befriend other teens who are also living with cancer, and it is here that Hazel meets her love, Augustus.

Through Hazel and Augustus's relationship after meeting in the support group, the two

are quick to support each other, pushing through their personal hurdles of cancer. They motivate one another to enjoy the little things in life: traveling, reading, picnics, and making the most of their lives. Sadly, towards the film's end, Augustus' cancer relapses, and the two must begin to process Augustus' limited prognosis. To do so, Grace and Augustus rehearse a funeral, where Grace can share her eulogy for Augustus:

HAZEL. Like all real love stories, ours will die with us. As it should... I'm not gonna talk about our love story, 'cause I can't. So, instead, I'm gonna talk about math. I'm not a mathematician, but I do know this: There are infinite numbers between zero and one. There's point one, point one two, point one one two, and an infinite collection of others... Some infinities are simply bigger than other infinities. A writer that we used to like taught us that. You know, I want more numbers than I'm likely to get, and God, do I want more days for Augustus Waters than what he got. But Gus, my love, I can not tell you how thankful I am for our little infinity. You gave me a forever within the numbered days. And for that, I am... I am eternally grateful. (01:42:52 – 02:05:51)

Through this tribute, Grace suggests that while her and Augustus' days are cut short, their relationship was enough to breathe life back into their numbered days.

Because Hazel and Augustus' cancer diagnoses facilitated their meeting, thus catalyzing their love story, it suggests how disability and sexuality are intertwined in both Grace's and Augustus' identities.

CASE STUDY 3: Moonlight (2016). *Moonlight* is a coming-of-age story that centers around the life of a black male protagonist, Chiron. The film is divided into the three stages of Chiron's life: his childhood, adolescence, and adulthood. Each stage captures Chiron's struggle with his identity arising from ongoing conflicts in his relationship with his mother, sexuality, and drug exposure. Overall, the film works to showcase the lasting impact early experiences can have on one's life trajectory.

Through the characters Chiron (also known as Little) and Juan, *Moonlight* highlights the intersection between race, class, and sexuality. The film portrays how systemic racism impacts the life of Chiron and his Miami community. For example, Chiron's mother struggles with addiction and poverty, which are both exacerbated by a lack of resources and opportunities in the poverty-stricken neighborhood of Liberty City. This particular instance becomes complicated for young Chiron, who learns that the individual responsible for supplying his mother with drugs is the man he looks up to the most as a fatherly figure, Juan. While sitting at the dining room table one afternoon, Chiron questions Juan about his profession:

CHIRON. Do you sell drugs?

JUAN. [pause] Yeah.

CHIRON. And my mama...she do drugs, right?

JUAN. [nods] Yeah. (00:34:53 – 00:35:24)

While Juan supplies Chiron's mom with the drugs that perpetuate her cycle of addiction, poverty, and maltreatment of Chiron, Juan does take the time to educate young Chiron about the importance of taking ownership over one's identity. Regarding race identity, Juan shares a story about the nickname "Blue":

JUAN. Let me tell you something, man. There are black people everywhere. You

remember that, okay? No place you can go in the world ain't got no black people, we was the first on this planet. [pause] I've been here a long time. I'm from Cuba. Lotta black folks in Cuba. You wouldn't know that from being here, though. I was a wild little shorty, man. Just like you. Running around with no shoes on when the moon was out. This one time, I ran by this old... this old lady. I was runnin' and hollerin', and cuttin' a fool, boy. This old lady, she stopped me. She said... "Runnin' around, catching up all that light. In moonlight, black boys look blue. You blue, that's what I'm gon' call you. 'Blue.'"

CHIRON. So your name 'Blue'?

JUAN. [chuckles] Nah.

JUAN. [pause] At some point, you gotta decide for yourself who you gonna be. Can't let nobody make that decision for you. (00:19:29 – 00:21:07)

In this scene, Juan stresses the importance of being one's true self. He urges Chiron to overlook the labels of others because this will give him the authority to take control of his own life. Juan gives a similar speech to Chiron when he asks about his sexuality after some boys at school bully him for being a "faggot":

CHIRON. What's a faggot?

JUAN. [pause] A faggot is... a word used to make gay people feel bad.

CHIRON. [pause] Am I a faggot?

JUAN. No. You're not a faggot. You can be gay, but... you don't have to let nobody call you a faggot. (00:33:27 – 00:34:05)

Similar to his racial identity, Juan again tells Chiron not to be confined by the labels of others. Juan validates Chiron's sexuality and encourages him not to allow others to belittle that part of him.

Through Juan and young Chiron's relationship, the audience learns about the impact and consequences of systemic racism. For example, Juan supplies the residents of Chiron's town with their drug needs. For Chiron, those drugs mean little money at home and an absent motherly figure who leans on him, a child, for stability. This creates an unsupportive home environment for Chiron, forcing him to navigate his sexuality independently. These domino effects reinforce the interconnected nature that race, class, and sexuality play in Chiron's identity.

CASE STUDY 4: Lady Bird (2017). *Lady Bird* is a coming-of-age film directed by Greta Gerwig. The film captures the story of high school senior Christine "Lady Bird" McPherson and her journey navigating her complicated mother-daughter relationship and the impacts of socioeconomic play in her day-to-day life. Throughout the film, Lady Bird aspires to leave her hometown of Sacramento, abandoning her past, to attend college on the East Coast. During her senior year, before her East Coast journey, Lady Bird can be seen enduring complications in many areas of her life, such as relationships, friendships, and family.

In the film, Lady Bird and Marion's mother-daughter relationship showcases the close connection between class and ability. Money can often be a point of tension between Lady Bird and her mother. In their family, Lady Bird tends to push her boundaries, encouraging her mother to splurge on items that are outside the family's budget. Consequently, Marion has to constantly remind Lady Bird of the family's financial state, insisting that she choose more affordable alternatives. An example of this can be observed while Lady Bird and Marion are out grocery

shopping:

MARION. We don't need to buy that.

LADY BIRD. It's only three dollars. I'm having a hard week.

MARION. Well, if you wanna read it, we can go down to the public library.

LADY BIRD. I wanna read it in bed.

MARION. That's something that rich people do. We're not rich people. (00:14:03 – 00:14:13)

Marion also goes out of her way to remind Lady Bird that wealth and happiness are not synonymous, and that she should not be equating the two. She urges, "Money is not life's report card... Being successful doesn't mean anything in and of itself. It just means that you're successful... But that doesn't mean that you're happy" (00:50:40 – 00:50:54). By constantly having to remind Lady Bird about the family's finances, it causes Marion to take on a more stern parental role with Lady Bird. This sternness interferes with a close mother-daughter relationship, leading Lady Bird to conceal the more intimate parts of her life, such as being on a waitlist for college. When the secret of Lady Bird's waitlist gets out, Marion is quick to isolate Lady Bird for hiding something behind her back, giving her the silent treatment. This silent treatment continues until the day Lady Bird leaves for college.

During her time living outside the family, Lady Bird comes to the realization of all the experiences she took for granted in Sacramento. Taking the step to mend her relationship with her mother, Lady Bird calls home:

LADY BIRD. Hi Mom and Dad, it's me, Christine. It's the name you gave me. It's a good one. Dad, this is more for Mom. Hey, Mom, did you feel emotional the first time that you drove in Sacramento? I did, and I wanted to tell you, but we weren't really talking when it happened. All those bends I've known my whole life, and stores, and the whole thing. But I wanted to tell you I love you. Thank you, I'm... thank you. (01:27:03 – 01:28:21).

Overall, because Lady Bird's abled body allows her to escape (through college) the confines of her mother alongside the confines brought on by Marion's stress of managing a low socioeconomic household, it suggests the interworkings that ability and class play in Lady Bird's identity.

CASE STUDY 5: Luca (2021). *Luca* is a Disney-animated coming-of-age film directed by Enrico Casarosa. Set in Portorosso, Italy, the film follows the life of Luca, a young sea monster, who wishes to explore the human world. Upon traveling above the sea's surface, Luca meets another young sea monster named Alberto. Working together, the two boys embark on a journey to win Vespa, the ultimate form of independence, in a local triathlon. During their training, Luca and Alberto meet a human girl named Giulia, who joins them in their race. Through these events, *Luca* showcases how one can overcome societal and cultural differences to achieve a common goal.



Figure 1: Sea Monster vs. Human Physical Traits. Image from Zach Johnson. “Meet the Characters of Disney and Pixar’s Luca.” D23, Disney, 15 June 2021, <https://d23.com/meet-the-characters-of-disney-and-pixars-luca/>.

In the film, sea monsters and humans are portrayed as two differing groups. These groups differ in aspects such as physical features and cultural values but overlap in areas such as aspirations. Given this information, the intersectional identity most prevalent in *Luca* is ethnicity. Concerning physical characteristics that notably distinguish the sea monsters from the humans, these features would include scales, fins, and tail. On the other hand, the physical features that notably distinguish the humans from the sea monsters include hair, skin, and legs. Both the sea monster and human characteristics can be observed in Figure 1.

Because both groups are not used to each other’s physical features, their differences instill fear, fostering prejudiced stereotypes against one another that each group is “dangerous.” An example of this instilled fear can be observed at the beginning of the film while Luca is herding his fish. While the fish were grazing, a motorized boat passes overhead, leading Luca to exclaim to them, “Land monsters! Everybody under the rock!” (00:05:40-00:05:46). The fish follow this command and huddle next to Luca under a cavern. Because the sea monsters have implemented safety practices to protect themselves from the humans, it suggests how their fear for them has ingrained itself into their culture.

A similar phenomenon can also be seen within the human’s culture. Contrary to the sea monster’s culture, rather than implementing safety practices, the town of Portorosso is littered with art displaying the murder of sea monsters (00:29:46-00:29:57). This art can be seen as a form of macroaggression. The humans are using the art as a form of propaganda that reinforces the stereotyping of sea monsters as scary, harmful beast, while also reinforcing that the appropriate response for a human when encountering a sea monster is violence.

As the film progresses, however, the sea monsters and humans begin to unveil similarities between the two of them. One of these similarities being their overlapping aspirations. For example, the sea monster characters Luca and Alberto hold the same goal as the human character Giulia: winning the town’s triathlon. Despite their differences, the three work together to

relentlessly train, which leads them to victory in the Portorosso Cup Race by the end of the film.

Ultimately, the sea monsters and humans defuse the tension between one another by accepting each other's "ethnic" differences and embracing their similarities.

Conclusion

After reviewing the five case studies, I found that 80% of the coming-of-age films showcased intersectional identities that contained two or more of Crenshaw's six aspects of intersectionality. The only movie that did not meet the standard of containing two or more of Crenshaw's six aspects of intersectionality was *Luca*, this film only showcased one.

However, my analyses uncovered another central identity not initially included in Crenshaw's six aspects of intersectionality; this identity is age. The influence of age made an appearance in each of the coming-of-age films reviewed:

The Perks of Being a Wallflower: Charlie notes the consuming infatuation of falling in love young.

The Fault in Our Stars: At her support group, Grace comments to everyone that death is inevitable and you do not have a say in when it happens.

Moonlight: Moonlight's narration style captures the impact that youth experiences have on future development.

Lady Bird: As an emerging adult, Christine changes her name to "Lady Bird," which symbolizes her first steps toward independence, separating herself from her family.

Luca: As an adolescent, Luca's transformation from sea monster to human symbolizes identity experimentation from Erikson's identity vs. confusion stage of psychosocial development.

Given the role that age plays in the life and experiences of the characters mentioned above, I argue that age could be a seventh aspect of Crenshaw's definition of intersectionality.

Discussion

Suppose intersectional identity representation in the coming-of-age genre has the potential to support the identity formation of adolescents and emerging adults. In that case, I argue that more attention should be directed toward the power of conscious consumerism and the power of intentional exposure.

Conscious consumerism acknowledges the fact that money holds power in our capitalist society. Money can purchase films that contain the representations individuals want to see. This transaction reinforces to producers the type of representations people wish to see in cinema. Furthermore, because producers need money to sustain their work, they are more likely to incorporate similar identity representation from selling films into future productions. This cycle could catalyze the flourishing of the female gaze in the film industry.

After purchasing the films, educators and caregivers can intentionally expose the film's

content to adolescents and emerging adults. Their exposure to intersectional identities, reinforced by conscious consumerism, could support the development of these populations as they navigate their journey to solidify a sense of self. However, intentional exposure can expand beyond just exposing youth to intersectional identities. It could also be practiced by sharing purchased films with other educators and caregivers or by sharing one's knowledge in person or online.

All in all, by practicing conscious consumerism and intentional exposure in day-to-day life, one has the potential to increase the production and distribution of intersectionally diverse films, which, in return, can support the identity development of our youth.

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Harnessing the Power of Methylootrophs for Bioelectrocatalysis: Lanthanum-dependent methanol dehydrogenase in *Methylobacterium Exorquens*

**Muhaison H. Ibrahim
Dr. Krysti Knoche Gupta**

Introduction

Bioelectrocatalysis is a rapidly growing field that focuses on using biological systems to power electrochemical reactions. Just like humans, the catabolic profiles of most organisms are built upon oxidation and reduction of chemical species. In humans, the majority of these redox reactions occur in the inner mitochondrial matrix, where the oxygen finally gets reduced to power the production of ATP for cellular use. This leads to the production of CO₂ and water. In plants, a similar process takes place in the thylakoid membranes of chlorophyll after prior consumption of CO₂ to produce oxygen, which ends up being used up by humans. Methylootrophs are exotic microorganisms that are known for their consumption and breakdown of organic compounds such as methane, methanol, as well as other two and three carbon species to produce energy. Since methylootrophs are very adaptable and resilient to harsh conditions, scientists are actively exploring the option of employing them as a means to generate energy for several purposes including biofuel cells, biosensors, and many other biotechnological applications.

In this review article, the goal is to provide a current state of knowledge on the bioelectrocatalysis of methylootrophs as well as recent advances elucidating the mechanisms of bioelectrocatalytic oxidation in other exoelectrogens and how that can be harnessed to power devices. This becomes more important as the need to mitigate environmental climate problems. Methane is one of the most abundant gases in the atmosphere that has significant effects on global warming. Presenting methane to methylootrophs for metabolism. The first being slowing down ozone depletion and the second being powering systems in a more conservative manner.

Enzymatic biofuel-cells

Enzymatic biofuels refer to a type of biofuel that is manufactured using enzymes. Their ability to generate energy depends on catalytic activities of the enzymes involved. Compared with traditional biofuel cells, enzymatic biofuel cells appear to be more advantageous given their diversity and ability to operate based on a variety of catalysts. Even though the optimization of biofuel cells has witnessed limitations, building enzymatic electrodes has been extensively studied. Currently, the most significant setbacks include the development of immobilizing materials, methods of immobilizing enzymes, optimizing enzyme electrode structures and shapes, and improving enzyme biocatalytic activity.

Wu et. al. has also explored the use of Laccase and NAD⁺ dependent dehydrogenase cascades as

biocatalysts on carbon nanodot electrodes to build methanol/oxygen enzymatic biofuel cell. They were able to efficiently assemble multienzymes-biocatalyzing electrodes for deep oxidation of methanol as well as DET-type electrode for four-electron reduction of oxygen.

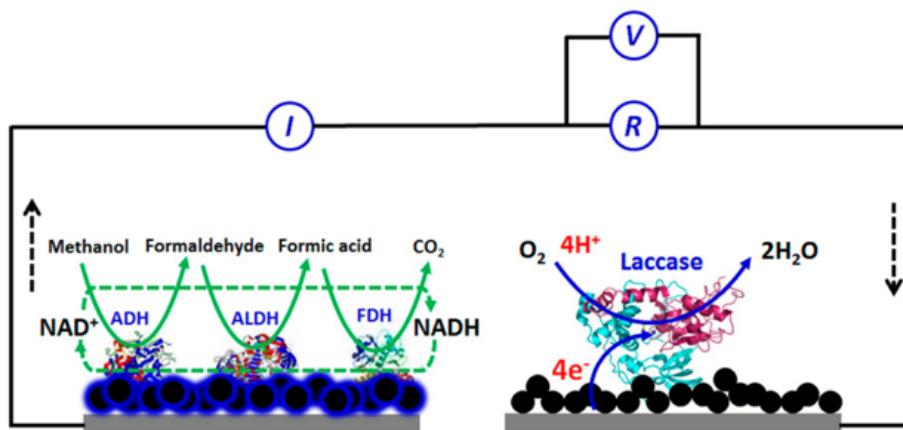


Figure 1. Schematic illustration of membraneless methanol/O₂ biofuel cell at carbon nanodots electrodes.¹

Electrochemistry of Methanol dehydrogenase

Methylotrophs, particularly *Methylobacterium Extorquens*, have been extensively examined given their expressions of *xoxf*, the gene that codes for *mxal* and *mxaf*, the small and large subunits of methanol dehydrogenase (MDH). The genome of the AM1 strain genome contained *MxaF*, *XoxF1*, and *XoxF2*. Both homologs of *XoxF* are crucial for the expression of MDH. The *XoxF* is a pyrroloquinoline quinone (PQQ)- dependent periplasmic alcohol dehydrogenase. The *MxaF* subunit of MDH has active sites residues and the afore mentioned PQQ prosthetic group which coordinates with Ca^{2+} . Currently, our lab is exploring the use of La^{3+} in lieu of Ca^{2+} as a cofactor for MDH. Prior studies such as Nakagawa et. al. in 2012, they were able to show that *XoxF1* functions as a La^{3+} -dependent MDH.

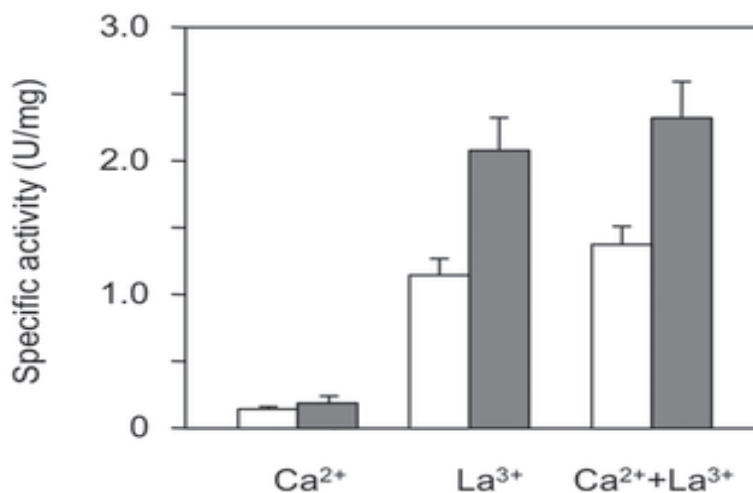


Figure 2. MDH activity in strain AM1 grown on methanol and succinate media with Ca^{2+} and/or La^{3+} .

The region downstream of XoxF encodes the cytochrome c, analogous to that found in human mitochondria, are responsible for electron transfer for energy production. Several mechanisms through which methylotrophs harness energy by oxidizing methanol has been proposed. Most of which include the serine and citric acid cycles as depicted in (Figure?)

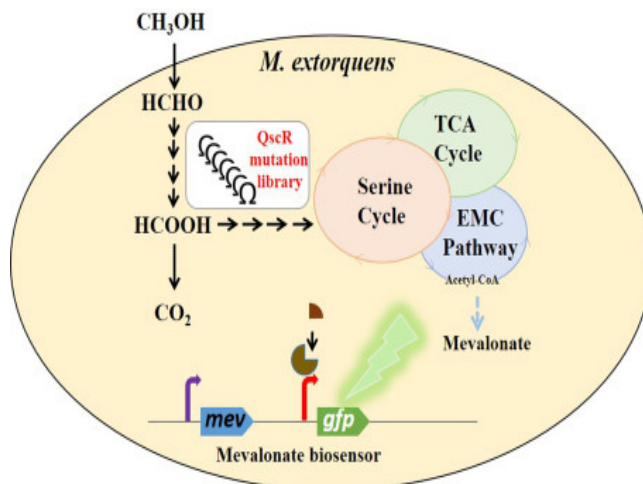


Figure 3. Biosensor-assisted transcriptional regulator engineering (SATRE) approach in *M. extorquens* AM1. QscR regulates the serine cycle to shift the carbon flux toward acetyl-CoA (Ac-CoA) accumulation. A heterologous mevalonate synthesis pathway responsible for converting acetyl-CoA into mevalonate was introduced into *M. extorquens* along with a mevalonate biosensor. The high mevalonate production mutants were screened out by fluorescence-activated cell sorting (FACS).

(This figure was modified from Liang, W., Cui, L., Cui, J., Yu, K., Yang, S., Wang, T., Guan, C., Zhang, C., Xing, X., 2017. Biosensor-assisted transcriptional regulator engineering for *Methylobacterium extorquens* AM1 to improve mevalonate synthesis by increasing the acetyl-CoA supply. *Metab. Eng.* 39, 159–168.)

Just like the human tricarboxylic acid cycle metabolized several compounds to create ATP by electron transfer, electrons obtained from methylotrophic catabolism of methanol is a great avenue for harnessing electrical power.

Developmental problems associated with Enzymatic biofuel cells.

As indicated earlier, enzymatic biofuels utilize enzyme catalyzed redox reactions to generate power. This means that there needs to be a succinct mechanism through which electrons generated from these enzymes are able to bind electrodes for further transfer. Of the many setbacks that could be expected in building enzymatic biofuel cells, this is most difficult to overcome as it predicts not just the longevity of the cells, but their efficiency and durability as well.

A myriad of research is ongoing regarding the optimum enzyme immobilization techniques on electrode. Our group over the past few months has been working on using tetrabutylammonium bromide (TBAB) modified Nafion® polymer. Essentially, having the enzymes bound to the electrodes leads to a better signal than having enzymes in solution. This is because electrons from electrode-bound enzymes are less likely to get repurposed as compared to their in-solution counterparts. This was one of the key things Dutta et.al. paid close attention to while designing

their single-enzyme biofuel cells (Figure). Specifically, they ensured direct electron transfer through electron tunneling between the T1 site on the anode (laccase Cu) and the T2/T3 site on cathode (laccase Cu) of a single enzyme. Per their results, this minimized electron transfer intermediates as the spatial distance between the T1 and T2/T3 redox centers were minimized. Subsequently, ABTS mediated electron transfer proved to be a great method of enhancing electron transfer between the active sites of enzymes and electrode.

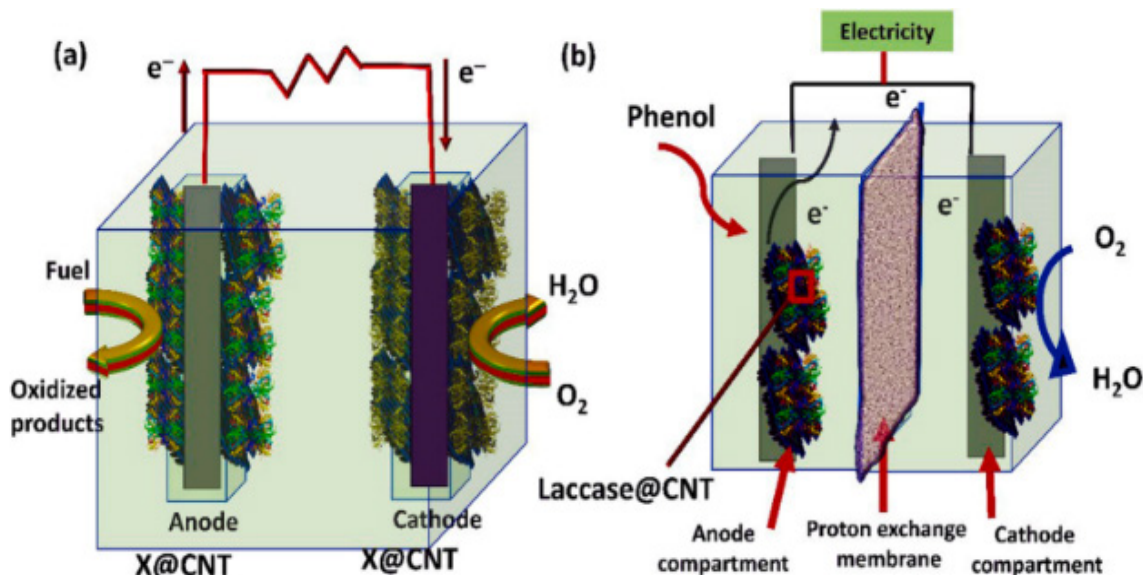


Figure 4. A comparative depiction of fundamental framework of traditional EBFC (a) and single-enzyme EBFC (b).

Possible solutions

Previously mentioned are several problems that pose hurdles in the quest to assemble biofuel cells. A few hypothetical solutions have been brought forth by various electrochemists for tackling hurdles ranging from low electron transfer efficiency between microbial cells and electrodes to issues related to longevity of the biofuel cells.

One very promising solution to these issues has to do with the incorporation of electron conduits in non-native exoelectrogens.^{xxx} Exoelectrogens are simply microorganisms capable of generating electrical energy through electron transfer. *M. Extorquens* is an example. This solution would require an intersection of synthetic biology and some engineering as the reprogramming or even genetic adjustments of biological species will be required. In recent years, . This approach is not a one size fits all solution. Instead, every microbial species is approached differently depending on the cells' extracellular electron transfer mechanism. Of the most commonly used non-native exoelectrogens for industrial and pharmaceutical applications are *E. Coli* and *P. Putida*.

This solution is becoming more feasible given the immense growth in synthetic biology. It becomes easier for model organisms' genetic background to Another advantage this approach provides is the possible use of the created exoelectrogens as chassis strains to create new cell factories through metabolic modifications.

Electron flux enhancement may also be another approach toward fine-tuning biofuel cells. There are about five different but successive steps through which electrons are generated from substrate oxidation. Through synthetic biology, each step could be modified to enhance the extracellular electron transfer pathway, increasing the flux of electrons through the systems.

Conclusion

Enzyme based biofuel cells are still under development and look more promising in their prospective use as biosensors for testing the presence of metabolites *in vivo*. In any case optimization of electron transfer within microorganisms as well as between microorganisms and electrodes is essential for effectively constructing a cell. As noted above, various methods of enhancing bioelectrocatalysis are being investigated. Some of the most promising efforts include making biofilms such as TBAB modified nafion to immobilize enzymes or microbes onto the surface of electrodes to enhance direct electron transfer. Other very promising avenues also include biologically modified microorganisms such that their extracellular electron transfer efficiency is optimized as much as possible. This could include genetically modifying the microorganisms to metabolize a large array of molecules efficiently or altering cofactors involved in enzymatic activity as the substitution of lanthanum for calcium showed higher enzyme activity.

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Exploring Clinical and Emotional Outcomes of Language Brokering During Childhood: Experiences of Emerging Adults In Immigrant Families

Cameron Merline

Abstract

Language brokering, the act of informal translation usually done by a child, has been known to create both negative or positive impact on children's development. Yet as common of an occurrence brokering is in immigrant families, no clear clinical outcomes, mediating factors of positivity/negativity of experiences, nor impacts on familial relationships have been thoroughly examined. This study has the goals of highlighting protective or risk factors that mediate whether brokering is a negative or positive experience for youth, learning about potential associations with self-efficacy, mental health issues, and stress tolerance, and examining whether brokering harms or strengthens family relationships. Through semi-structured interviews with 4 participants from immigrant families, no definite connections can be made between language brokering and mental health outcomes or changes in familial relationships. Supported is the idea that there may be a connection between language brokering and the development of positive skill sets along with higher retrospective reports of everyday stress.

Background

In families who have recently immigrated to the United States, it is well established that children tend to learn English and incorporate cultural norms into their lives more quickly than their parents (Martinez, 2009) through schooling. Because of this difference in language ability, children in these families tend to take on the role of language broker; defined as the practice of interpretation and translation between two parties that linguistically differ (Tse, 1995). As language barriers have been identified as an imminent stressor for recent Latino immigrants (Padilla, Cervantes, Maldonado, & Garcia, 1987), many parents inadvertently begin to depend on their children for language translation. Differently than a professional translator, a language broker is untrained and often restricted by their own communicational and linguistic proficiency. This is where the controversy of children serving as translators begins. Although language brokering most commonly occurs in everyday ways like grocery shopping, explaining single words, or relaying the message of a phone call, it can also be seen in more complex situations such as medical, educational, commercial, or legal settings (Orellana & Pulido, 2003; Tse, 1995). Language brokering is known to have various positive impacts (i.e increased responsibility, independence, maturity (Anguiano, 2017), and confidence (Kam & Lazaervic, 2014)), or negative impacts (i.e., increased depression and anxiety symptoms (Arellano et al., 2018; Rainey, 2014; Anguiano, 2017), and stress on development (Anguiano, 2017; Kam & Lazarevic, 2014)). However, some variables like academic success can be impacted both positively (Kam & Lazarevic, 2014; Anguiano, 2017) and negatively (Anguiano, 2017; Tse, 1995), and factors that mediate variables like these have only been somewhat examined. One additional area of

language brokering that lacks adequate research is its impact on familial relationships (Straits, 2010). Very few studies have directly examined the relationship between language brokering and both parent and sibling relationships, specifically looking at whether they are strengthened or weakened by an individual's experience with brokering. A more in-depth examination of how family-child relationships change across time can lead to more adequate supports for youth who are most likely to engage in brokering, along with creating a more complete prediction of how family dynamics are likely to be impacted by immigration. Overall, it has been questioned whether language brokering has a negative or positive impact on children's development, or even any impact at all. As 14.1% of the U.S. population is of immigrant status (Jordan & Gebeloff, 2022), a significant portion of children in the country have the potential to be affected by brokering, yet there are still no certain conclusions surrounding this phenomenon. As results have varied since increased interest in this topic, additional research is necessary to create a more comprehensive understanding of the act of language brokering and its potential impacts on emotional development, clinical outcomes, and familial relationships.

Present study:

This study has goals of highlighting protective or risk factors that mediate whether brokering is a negative or positive experience for youth, learning about potential associations with self-efficacy, mental health issues, and stress tolerance, and examining whether brokering harms or strengthens family relationships. These goals are to be achieved through qualitative, retrospective, semi-structured interviews with adults from immigrant families, with the hopes of looking at language brokering from multiple dimensions (i.e., brokering context, change over time, family dynamics, participant age, and cultural differences). More specifically, I would like to answer the research questions of: (1) does language brokering during childhood contribute to healthy self-efficacy or mental health issues? Which it is predicted that language brokering during childhood will be positively associated with both mental health issues and increased self-efficacy, (2) what impact does language brokering have on self-perceived stress levels during childhood? What seems to mediate the kind of experience it is? Which it is predicted that language brokering during childhood will be associated with higher retrospective reports of stress. And (3) does language broker lead to more positive or negative relationships with family members? Which it is predicted that language brokering during childhood will be associated with more negative relationships with parents but more positive relationships with siblings.

If the impacts of language brokering are thoroughly understood, mental health professionals in schools and health care settings can be better informed on how to support the youth of immigrant families, providing a more fine-tuned intervention. If possible negative effects are uncovered, there is also potential to implement resources that may decrease the need for children to broker in certain settings or create educational resources for parents of immigrant families to counteract negative impacts.

Methods

Participants:

Four adults who had partaken in language brokering in their youth or adolescence were recruited to participate in this study. A description of the study (Appendix A) was posted to the researcher's social media and those who were interested contacted the researcher to receive informed consent and follow-up messages to schedule an interview. No incentive was provided for participation in this study. Community members tended to send the study information to those whom they thought might be interested in participation. Two respondents disclosed that they were uncertain of or had few memories of brokering as a child, hence they were excluded from the study. The participants ages ranged from 23-50 and all identified as female. One participant was Mexican American, one was Mexican, one was Korean, and the last was Chinese. Two of the participants were bilingual in Spanish (as their native language) and English, one was bilingual in English (as their native language) and Chinese, and the last was fluent in English (as their native language) and only knew some Korean (their family's native language).

Table 1: Demographics and Descriptive Information

Participant	Age	Ethnic Background	Country Born In	Languages Known	Generation in the United States	Sibling Birth Order	Number of Parents in Household	Primary Language Broker
Jenna	48	Korean American	Korea	English, some Korean	Second	Middle of three	Two (father was American)	Yes, younger brother did some after she moved
Marcella	31	Mexican American	United States	Spanish, English	First	First of five	Two	Yes
Claudia	50	Chinese American	United States	English, Chinese	Second	Last of three	Two	No, older sister was
Karmen	24	Mexican	Mexico	Spanish, English	First	First of three	Two	Yes

Interview Process:

After recruitment, participants gave verbal consent to participate in this study and be recorded while on a Facetime or Facebook Messenger call. The data for this study was collected using individual, semi-structured, 30-90 minute online interviews, which were transcribed and coded afterwards. All participants were given a shortened copy of the interview protocol to review beforehand. This was put in place to help alleviate anxiety, as there were sensitive questions included which participants were allowed to skip at any time.

The interview protocol used was adapted from a similarly designed study (Esquivel, 2012) and aimed to address the present study's research questions (See appendix). Four broad categories were addressed during the interview: participant background, their experiences

with language brokering, stress and mental health, and family relationships. Beginning with questions like “could you tell me a bit about you and your family?”, the researcher aimed to better understand the participant’s backgrounds and get them comfortable sharing information. To examine the experience of language brokering, questions such as “tell me about your first experiences as a language broker” and “in general, how do you feel about language brokering?”. Mental health was addressed by simply asking “do you have any mental health issues you feel comfortable sharing about?”. Familial relationships were examined using questions like “could you tell a little about your relationship with your family?” and “do you think language brokering or roles taken on during your childhood have altered the way you feel about your family?”. Depending on the type of answer the participant gave, the researcher may have probed using phrases like “how often did you broker for others?” to get further insight. As these interviews were not fully structured, the researcher typically let the participant talk about whatever they felt was relevant to their experience, only stepping in to keep the conversation going or introduce certain topics around the research questions.

Data Analysis:

Audio files from each interview were imported into the program Otter AI, where they were automatically transcribed. After review from the researcher, transcribed files in the form of word documents were imported into the software MAXQDA.

Interviews were hand-coded according to themes around the research questions that were expected to emerge: background, language brokering, mental health, family relationships, and any unexpected themes were coded as a subcategory under their larger theme (Table 2). Afterwards, data was compiled in a separate word document and divided amongst each research question and participant to get a better picture of trends.

Table 2: Code System

Code	Frequency
1 Background Information	1
1.1 RED HIGHLIGHT	55
2 Language Brokering	1
2.1 Learned skills/strengths and weaknesses	16
2.2 Impact on social/school	8
2.3 Did you understand your role	4
2.4 Kind of experience (+/-)	34
2.5 How often	2
2.6 Where did it occur	16
2.7 Age of first experience	5
3 Mental Health	13
3.1 Stress	2
4 Family Relationships	2
4.1 Parent relationship	13
4.2 Still brokering for family	4
4.3 Brokering’s impact on family	10
4.4 Sibling relationship	18

Note: Major code categories and subcategories and their combined number of occurrences in all four interviews.

Results

As this study examined the phenomenon of language brokering from multiple dimensions and across time, the results section will summarize findings from several aspects of language brokering.

Common Characteristics of Brokering:

A question asked across interviews was at what age did the participant begin language brokering; to which there was an age range from 8 to 13 years old. Additionally, brokering occurred in a multitude of settings, such as in the home (N=2), for business matters (lease contracts/utilities/bills) (N=1), educational (N=1), stores or restaurants (N=4), medical (N=2), and legal (N=2), but all participants said that it was most often “little everyday things” they would interpret and that it was not an everyday occurrence to interpret or translate in more formal settings. None of the participants mentioned having to translate every day for their family or community members.

Learned Skills:

Each participant shared diverse ways that the experience of language brokering influenced both their childhood and their life currently (Table 3). Many participants shared how influential brokering was on their public speaking and communication abilities today. Jenna shared that she has “always been extremely strong with the English language. So much that in high school, [she] actually won awards for it. So [she] doesn’t think that’s a coincidence”. Marcella mentioned that she gained self-advocacy skills, but did not elaborate on what ways. Similar to others, Claudia said, “I think I actually helped me, because, I think in communicating with people. Especially like interviewing and my first jobs and stuff like that”. All four participants mentioned in some way that brokering had enhanced their financial or life skill abilities in general, whether this was in learning early on how to pay bills (Marcella), being bilingual (Karmen), or learning attention to detail (Jenna). Lastly, Jenna and Claudia shared how their experience of translating for parents had altered their perceptions of society. In negative ways, Jenna shared that she “Dealt with some of the discriminatory things early on” and “always [felt] like she [didn’t] fit in”. But in positive ways, Marcella, Jenna, and Claudia all shared that their experiences broadened their views of the world. Each of these participants shared how growing up in a multicultural environment gave them increased awareness of “how society works”. When asked to elaborate, participants struggled to verbalize in exactly what ways their views were influenced; one participant, Claudia, sharing that she was glad she just “knows what [she] knows”. It is unclear whether the act of brokering or being raised in a multicultural environment most directly led to changes in world perception.

Table 3: Common Learned Skills

Participant	Communication/Public Speaking Skills	Influenced Perceptions of the World	Financial/Life Skills
Jenna	Yes	Yes, in negative ways	Yes
Marcella	Yes	Yes, in positive ways	Yes
Claudia	Yes	Yes, in positive ways	Yes
Karmen	-	-	Yes

Impact on Social Life or Education:

When asked to discuss how brokering impacted participant's social lives or education in their childhood, only two participants had experiences to mention. Jenna had a unique experience while growing up; as her father was actively serving in the military, she was born in Korea, raised in various cities in Europe, and then moved to the United States with her family. When talking about her middle school/high school friendships in Europe, she said "I also went to school with people that were, you know, mixed race, and they shared the same experiences. And throughout these 30 years, like we still keep in contact, and we're still unbelievable friends". Jenna shared how she valued the common experiences (whether surrounding brokering or not) that she had with other mixed-race students. Karmen was born in Mexico and immigrated to the States with her mother before the third grade, and she shared that she doesn't remember any significant negative or positive impacts that the experience of brokering had on her social life.

Mental Health:

Across all four interviews, each participant chose to share that they do have mental health issues currently. These issues were varied from person to person and anxiety was the only common issue across more than one participant. The mentioned issues were anxiety (N=3), depression (N=1), and post-traumatic stress disorder (N=1). Through discussions, it does not seem like any of these mental health issues were clearly related to the experience of language brokering. One participant mentioned that "it was more like a cultural thing rather than a translating thing", and another mentioned that she "doesn't think the language [brokering *inserted for clarity*] really affected [her] mental health".

Type of Experience Brokering Was:

This category of questions brought up the most complex answers with no clear theme either. Like other literature, it was concluded that the experience of language brokering cannot be categorized as either positive or negative. As expected, the responses of each participant varied greatly; some stated that the experience fluctuated between being negative and positive throughout their childhood, others shared that even they cannot say whether it was positive or negative, and yet others said that it depended on the situation (Table 4). Additionally, participants tended to describe their role of language broker as a duty, role, or service to their parents specifically, even though they often described the experiences as irritating, frustrating, weird, or stressful. Jenna was the only one who described her brokering experiences as clearly positive, saying "but overall, I would say it was positive, because in one aspect, it made me closer to my mom for sure". On the other hand, Karmen and Marcella described the experience in more neutral ways such as relaxed and normal (Table 4). In connection with this, all individuals interviewed shared that they felt as if they wanted to be helpful to their families through statements like "I wanted to help my parents in any way. [This] was a way I could help them", "I always like, like helping my mom understand things", and "I knew [mom] needed help and I was the only one who could do it". Overall, it seems like even though participants used negative words used to describe the experience of language brokering, these negative feelings may just exist in the moment of having to translate and not carry over to other interactions with family. It could also be that the mentality that most participants held of wanting to be helpful to their

family may have mediated or softened how negative the experiences of brokering were.

Even though it looks like experiences tended to be more positive or neutral than negative, participants still often mentioned that particular experiences were more stressful. Jenna noted that the fact that brokering was “something most people don’t have to do” contributed to her feelings toward translating. Both Marcella and Karmen discussed how they struggled with translating in legal settings due to the use of vocabulary they were not familiar with. Marcella said “the only times that it was stressful was when it came to like legal paperwork. Those are the only times I remember being [it being] stressful because you want to fill out paperwork the right way. Because every single process, it’s like another \$100 that you know your parents don’t have, so you should do it correctly”. Marcella mentioned that in a legal setting it was more difficult when she did not know the high vocab words, especially because she knew how to translate them but not what they meant. Karmen also talked about not knowing “big words” while translating for her dad and felt “it took something from [her when she was] being compared to [others], because [she] couldn’t translate to the level of somebody else”. It should be noted that this only occurred with one parent, and she said, “see for my mom, I didn’t mind as much because she was like nicer about it”. The experiences described by Karmen may hint at parent-child interactions being a mediator of the type of experience brokering is in youth. Both Marcella and Karmen shared with me that the “stress [they] experienced was one they did not want at eight years old”.

One background factor was the difference in experience that participants had when English was their first language compared to when it was not (Table 4.1). Both Marcella and Karmen learned English at a later age, and both mentioned that they struggled to translate higher level vocabulary words while brokering in a legal setting. Karmen specifically mentioned that her “mom saw how like, [she] struggled with like learning language a little bit”. This might suggest that those who are learning English at the same time as translating it in, along with being in situations that require a language competency higher than their own may lead to a more stressful brokering experience during youth.

Table 4: Type of Experience Brokering Was for Participants

Participant	Negativity/Positivity of Experience	Language Used in Equivalency to Brokering	Words/Phrases Used to Describe Experiences
Jenna	Positive	Duty, Filial Duty	Annoying, Stressful, Frustrating, Time Consuming, Caught Between Two Cultures
Marcella	Cannot define as positive or negative	Role, Service	Felt Normal, Irritating, Relaxed, Indifferent
Claudia	-	-	Felt Weird
Karmen	Indifferent, A Little Positive	-	Didn’t mind, Normal, Felt Compared to Others, Pressure, Stress

Table 4.1: Type of Experience and Mediating Factors

Participant	Negativity/Positivity of Experience	Mentality Towards Family	First Language	Age English was Learned	Sibling's Language Skills During Participant's Youth
Jenna	Positive	Wanted to be helpful	English	-	Fluent in English, Don't Know Korean
Marcella	Cannot define as positive or negative	Wanted to be of service	Spanish	6 th Grade	All Fluent Spanish, 3 of 4 Did Not Know English
Claudia	-	Was a "fixer", Grateful to Parents and Wanted to Help	English	-	All fluent in English and Chinese
Karmen	Indifferent, A Little Positive, A Little Negative	Liked being helpful	Spanish	3 rd Grade	All Fluent in English, Don't Know Spanish

Family Relationships:

Overall, all participants reported that their relationships with their parents remained positive throughout life, often becoming more positive with time. Daily communication, freedom to express personality, and feeling comfortable asking for help from parents were some of the most common aspects of supportive parent/child relationships discussed in participant interviews. Although these relationships remained strong, tough feelings in each family were not left out of conversation. Jenna shared that she felt her family was "caught between two cultures" and believed this had a negative impact on the family overall. In a family of five children, Marcella voiced feeling that she "hated how [my] parents made me a "parent" [when she was] so young". Marcella had an authoritative role over her siblings; her responsibilities involved making sure her brothers and sisters had their homework completed and in her young adult years she was temporarily the sole guardian for two of them. This participant said "[she does not] have the perfect relationship with them" and she "didn't want the stress that they brought". All four participants shared that they did not have strong relationships with their siblings in the past, evidenced by "pushing away" or "distancing" self from siblings, sharing about "back and forth" relationships, or not seeing and talking to siblings for years, but are currently making efforts to repair those relationships. Through discussion with these each of these participants, it seems like the negative aspects of their sibling relationships are due to situational factors, ones that are unrelated to language brokering.

Discussion

The data collected provides direction to each of the research questions of the present study. Research question one asked: does language brokering during childhood contribute to healthy self-efficacy or mental health issues? From the data collected, nothing can be said about language brokering in connection to mental health, but perhaps there is a connection between language brokering and the development of positive skill sets. All participants mentioned feeling

strong in their communication skills, English language, and public speaking skills, which are all beneficial all throughout life. These results somewhat supported the hypothesis that language brokering during childhood will be positively associated with both mental health issues and increased self-efficacy.

Research question two asked: what impact does language brokering have on self-perceived stress levels during childhood? What seems to mediate the kind of experience it is? The data collected shows that participants did have both stressful and low-stress experiences while brokering. None of the stressful feelings shared seemed to continue outside the act of translating, which may suggest that stress in connection to language brokering is short-term and situational. Additionally, mediators of how stressful typical experiences seemed to depend on the dynamic of the participant's interactions with the parent they are translating for, whether the parent is understanding and supportive of the child; how strongly the participant feels connected to their family in terms of seeing brokering as helpful or their duty; and whether English is the participant's first language, the age they did learn English, and how confident they are in their language skills. This supports the prediction that language brokering during childhood will be associated with higher retrospective reports of stress.

Research question three asks: does language broker lead to more positive or negative relationships with family members? Data collected cannot support any trend between language brokering and changes in family relationships, both with parents and siblings. It seems like both negative and positive aspects of the relationships discussed in each interview were the result of factors surrounding the stress of immigration, living situations, or parentification associated with family dynamics.

As the sample size was only four, no conclusive connections between language brokering and mental health outcomes could be made. In relation to the connection between one's experience with brokering and personal background information though, there are likely weak connections that can have the potential to be expanded in further research.

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Appendix

(A) Interview Protocol

Background: (Adapted from Esquivel, 2012)

- 1) Tell me about yourself, your background, and your family.

Language Brokering:

- 2) Tell me about your first experiences as a language broker, that is, interpreting and translating for your family and community members.
- 3) In general, how do you feel about language brokering? (Change over time)
 - How thoroughly did you feel that you understood the role you were playing as a child?
 - How do you think these experiences influences your stress levels as a kid? How do you handle stress currently?
- 4) How do you feel that these experiences have influenced you long term?

Mental Health:

- 5) Do you have any mental health issues you feel comfortable sharing about?
 - When did you first notice those arising?
 - What sort of effect do they have on your day-to-day life?

Current Family Relationships:

- 6) Could you tell a little about your relationship with your family?
- 7) Tell me about the time your family currently spends together?
- 8) Do you still language broker for any of your family members?
- 9) Do you think specifically language brokering or roles taken on during your childhood have changed the way you feel about your family?

Conclusion:

- Do you have any other things you would like to share with me?
- Thank you for your time!
- I appreciate your openness and willingness to share personal and sensitive parts of your life with me.
- I am excited to take what I've learned from your story and inform others on the experiences that language brokers, like you, in their youth have.

(B) Social Media Post for Recruitment

Hello, my name is Cameron Merline and I am a senior psychology major at the University of Wisconsin – Eau Claire. I am currently working on a final research project with the goal of gaining insight into the experiences of language brokers (defined as the act of translation by youth for an adult who is less fluent in the dominant language) through short interviews that can be in person or via Zoom.

I hope to learn about:

- What influences the kind of experience brokering is for people

- Brokering's impacts on self-efficacy, stress, mental health, and family relationships

All interview questions would surround these topics, and it is understood that feelings of anxiety, stress, or discomfort may arise from certain topics. Participants would have the full right to skip any questions they wish to or stop the interview at any time. Additionally, participation in this study will be kept anonymous via the use of pseudonyms.

If you are over the age of 18 and have served as an informal translator in any way during your youth, I invite you to participate in this study and have a low-stress chat with me! I would love to learn more about your experiences!

If interested and would like to learn more, send a quick email to me at merlincp4954@uwec.edu



Does *Monotropa uniflora* produce grayanotoxin?

Sandra Prickett
Dr. Michael Walsh

Abstract

Finding new pain management therapies will mitigate the effect addictive opioids have on our society. One folk medicine that shows promise as a pain management tool is *Monotropa uniflora*. *M. uniflora* is a member of the Ericaceae family of plants, many of which produce a neurotoxin called grayanotoxin (GTX). The primary purpose of the experiment is to determine if the alcohol extraction of *M. uniflora* affects MCF-7 cells in the same way as other Ericaceae family plants that produce GTX to explain the reaction people reportedly have with *M. uniflora* extract. Previous studies concerning *M. uniflora* were studying antimicrobial activity of the ethanol extract, among other solvents. The physiological effects of *M. uniflora* extract on human cell culture have largely been unexplored in western literature. By studying the dosage effect of the ethanol extract in human breast cancer (MCF-7) cells, the activity of *M. uniflora* extract can begin to be characterized via Raman spectroscopy. Preliminary findings suggest that the *M. uniflora* ethanol extract effects the MCF-7 cells independently of the ethanol solvent. Additional analysis is continuing to expand effects across time to determine if the cells are metabolizing the extract and solvent differently. Comparing Raman characterization between *M. uniflora* extract with characterization of GTX in MCF-7 cells will give further evidence to determine whether *M. uniflora* produces GTX and lend to future research determining if either are safe alternatives to opioid analgesics.

Introduction

Monotropa uniflora, commonly called “ghost pipe”, is a white holoparasitic plant that thrives in lower pH soils where wild low-bush blueberries can be found. Such habitats where the presence of *M. uniflora* have been recorded are older, secondary growth deciduous forests with full canopy cover and a robust mycelium community in a mutualist relationship with the trees (1). Current research studies focus on *M. uniflora* in plant diversity surveys (2,3) or are concerned with trying to grow the plant in laboratory settings (4,5). An older paper from 1951 studies the use of various solvent extractions of many plants for antimicrobial activity. Extracts of *M. uniflora* were placed in the top ten most antimicrobial plants (6). Only one source from 1889 determined that *M. uniflora* may contain a neurotoxin (7) but has not been reproduced because the methods of extraction have changed and improved significantly since 1889. There has not been enough investigation into potential therapeutic properties of *M. uniflora* despite many non-biomedical sources suggesting that the plant has pain relieving properties (8–10). A common consensus between homeopathic practitioners, folk medicine authors, and YouTube videos is that ghost pipe

is used to treat pain, anxiety, and insomnia (8–13), however, there is little to no literature further confirming the presence of grayanotoxin in *M. uniflora*.

The plant is used as an antinociceptive, anti-anxiety and anti-insomnia medicine, these effects could be explained by GTX. The mechanism for GTX has been demonstrated as binding to sodium voltage channels in cells, causing depolarization at a resting state in nerves (14). This necessitates stronger stimuli to meet the activation threshold, resulting in lowered nociceptive and sympathetic system communication. Four of the common grayanane diterpenoids studied have varying toxicities and efficacies. Sun et al. report that GTX-1 and GTX-4 showed analgesic properties more potent than morphine (15).

Figure 1.

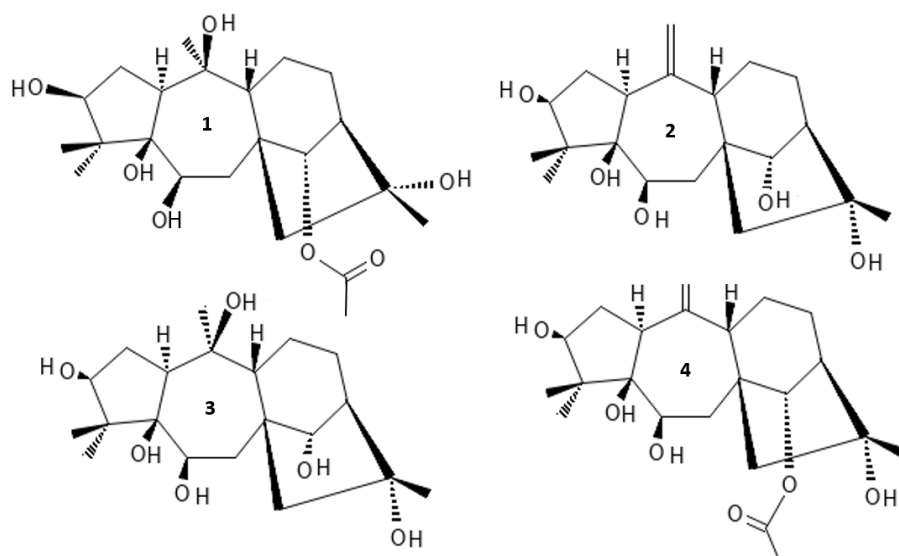


Figure 1. Structures of grayanotoxin 1 through 4. Figure 1 was made using the National Institutes of Health PubChem Sketcher V2.4.

The major difference between GTX-1 and GTX-3 is the hydration of the acetate group under the ring, allowing the acetate to leave due to warmer temperatures (16), shown by Figure 2.

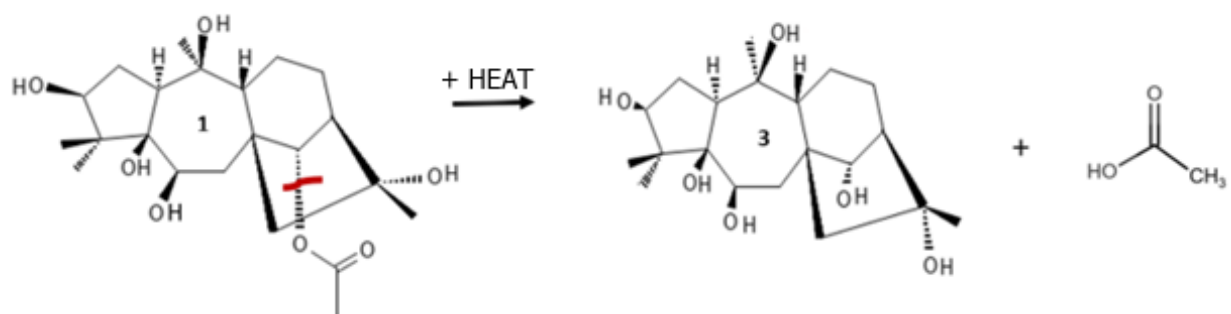
Figure 2.

Figure 2. Heat causes the ester group to leave the ring, turning GTX-1 into GTX-3. Figure 2 was made using the National Institutes of Health PubChem Sketcher V2.4.

GTX naturally occurs in other Ericaceae plants such as *Kalmia latifolia* (mountain laurel) and Rhododendrons (15,17–20). Rhododendron sourced GTX is currently being studied in the form of Rhododendron honey in the Middle East. From over 1,199 case studies, the average dose people take of Rhododendron honey (RH) is 20 to 100 grams, used mainly to self-treat hypertension and sexual enhancement. There are no records of people dying from an overdose of RH since the 1800s, as those who are admitted to the emergency room present with a low pulse rate and a drop in blood pressure; these symptoms are treated with atropine after confirming RH consumption (21). Besides RH, GTX can be obtained by exhaustive extraction from Rhododendron leaves. In 1889, Professor Plugge noted that andromedotoxin (GTX) is highly soluble in ethanol (7), as seen in contemporary studies which use an exhaustive ethanol extraction process described by Lechtenberg et al. (18), Li et al. (19), and Sun et al. (15). While Rhododendrons produce abundant plant material to extract from, *M. uniflora* does not. Since the effect of GTX on cells is known, a comparison can be made between cells in 2D culture dosed with an ethanol extract of *M. uniflora* and cells dosed with GTX.

Methods

Raman spectroscopy can detect subtle biochemical changes in the composition of biological samples, which can overcome the limitation imposed by the relative rarity of *M. uniflora*. Visible light lasers are used to excite the covalent bonds between atoms, which allows Raman spectroscopy to detect biochemical markers without incurring damage to the sample. While Raman spectroscopy cannot detect changes in ion content directly, it can detect changes in the bond stretch of water molecules as a result of ionic solute changes, indicating cell depolarization due to GTX introduction into the cell media.

MCF-7 human breast cancer cells are well characterized by Raman spectroscopy (22–26), which are hardy in 2D culture environments and have a quick doubling rate, making MCF-7 cells suitable for dose studies focusing on small cellular changes under Raman spectroscopy.

Ethanol extracts are commonly called tinctures in alternative medicine and can be made by the general population (11-13). Since tincturing is the common method of preparation and consumption for *M. uniflora*, a tincture is used in this study similar to RH studies (27–30).

Limitations in RH studies showed that RH varied in concentration of GTX, which produced a large variance of signal. However, since the subjects of RH studies were living animals, more GTX needed to be present to give consistent results. There may be more GTX present in the aerial part of *M. uniflora* on average compared to relative amounts of Rhododendron nectar in RH collected by bees in the Black Sea region.

M. uniflora tincture was prepared by sustainably harvesting the aerial parts of fresh flowers from July to October, sectioning and placing into a container to fill $\frac{3}{4}$ by volume, moderately packed. Ninety percent ethanol was poured into the container approximately one inch above the plant material and agitated twice weekly in storage for 6 months in a dark, cool, dry space for extraction. The transparent and clear ethanol turned black and cloudy during extraction time.

Experimental design 1: to determine if M. uniflora extract has any activity on MCF-7 cells.

MCF-7 cells were seeded in T-25 flasks in high glucose Dulbecco's Modified Eagle's Medium (DMEM), containing 10% fetal bovine serum, incubated at 37°C in an atmosphere of 5% CO₂. The ethanol concentration of the ethanol solvent group and the *M. uniflora* tincture concentration were kept the same at 0.225% ethanol by volume per internal lab protocols. After proliferation to 80-100% confluency, 3 replicates of 3 treatment groups were tested: null treatment, ethanol treatment (OH), and extract treatment (EXT). Three replicates were exposed to the treatments for 10 minutes and 2 days after a 24-hour period when the treated media was refreshed. Each sample was fixed to aluminum Raman slides with 70% ethanol and scanned using a 532 nm wavelength laser for 8 replicates of 20-second exposure.

Experimental design 2: to determine M. uniflora time-course effects.

MCF-7 cells were seeded and split into null-control group, OH group and EXT group similar to the first experiment. However, the times of exposure were changed to 20-minute intervals until 80 minutes had elapsed. Raman spectra of each sample were taken in 15 replicates under the same conditions as the first experiment.

Results

The Raman spectra were analyzed with the unsupervised multivariate analysis (MVA) technique, principal component analysis (PCA), and the supervised MVA technique linear discriminant analysis (LDA) program to return a scatterplot, known as a scores plot, to determine if there are differences between groups. Points that appear close together on a scores plot have similar spectral similarity, and thus biochemical similarity. This approach allows for the visualization of clustering of cellular biochemistry on a 2D plot as seen in figure 3.

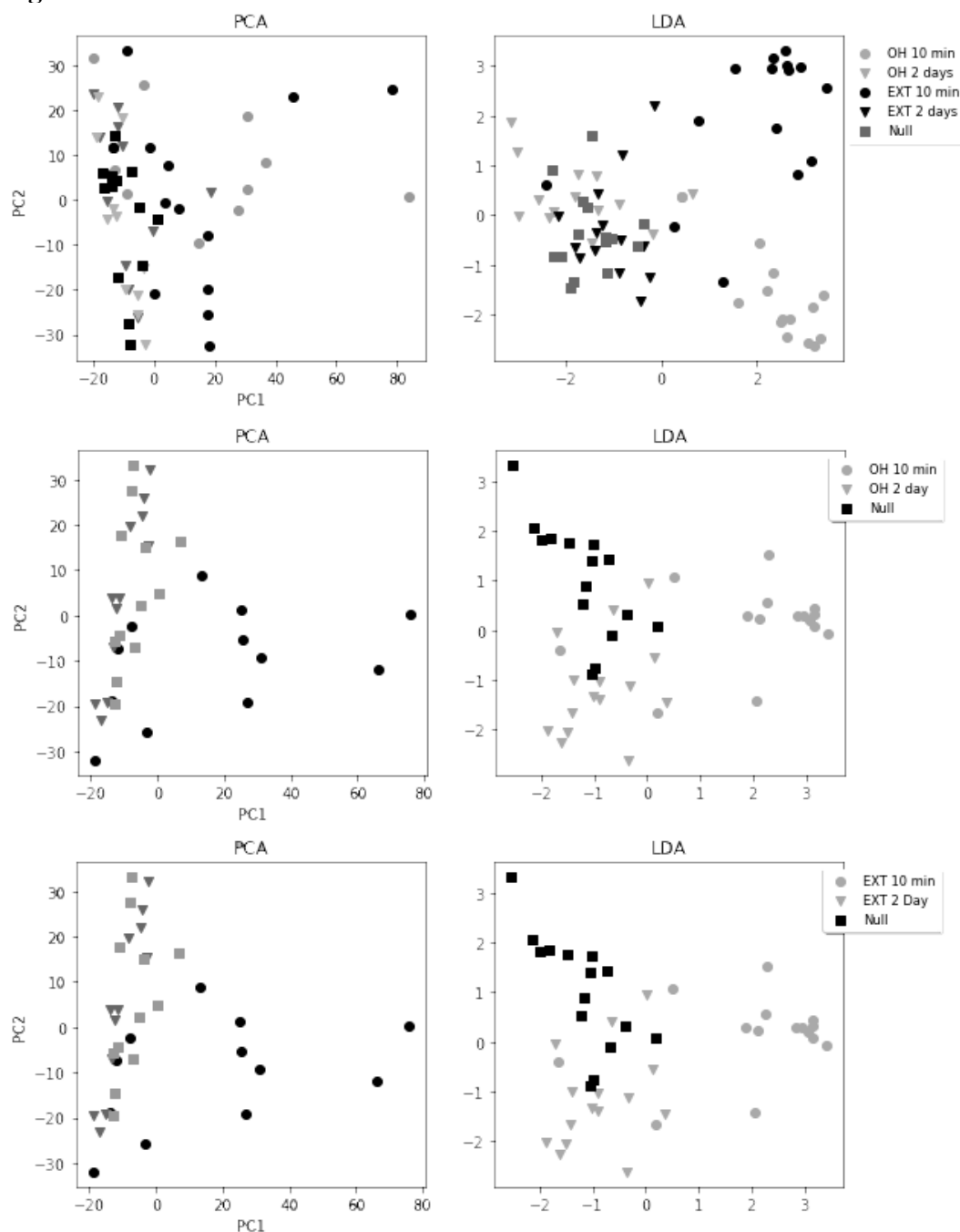
Figure 3.

Figure 3 shows the PCA/LDA scatter plot results from experiment 1. The 10-minute extract treatment group (EXT) showed significant differences from both the null group and the 2-day EXT exposure group. The 10-minute ethanol solvent group (OH) also shows significant differences from both the null group and the 2-day OH exposure group. When all groups are examined together, both the 2-day EXT and OH groups are similar to the null group. However, the EXT and OH 10-minute groups are significantly different from each other as well as the null and 2-day exposure groups. These results show that the *M. uniflora* extract has some effect on the MCF-7 cells that are different than the ethanol solvent.

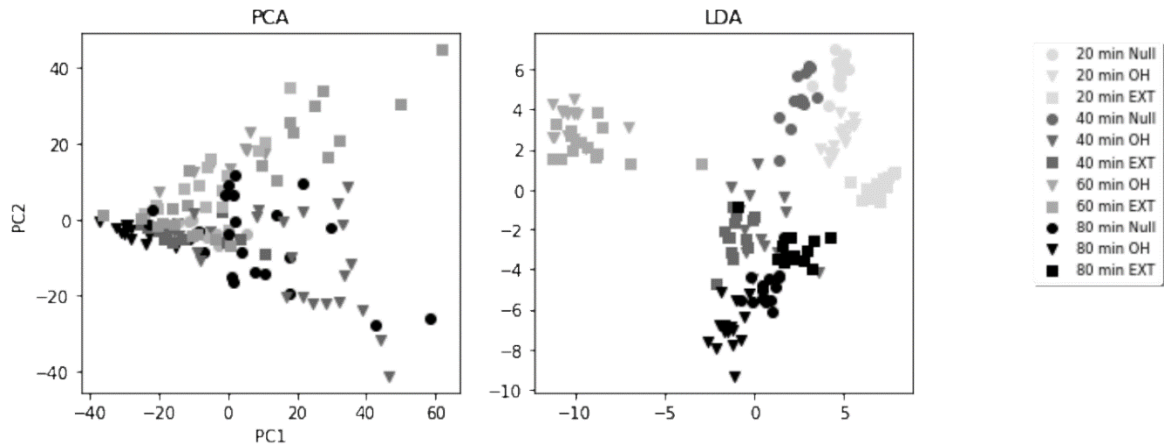
Figure 4.

Figure 4 shows the PCA/LDA results of experiment 2. The 20-minute exposure OH and EXT groups cluster apart from each other and other groups in the LDA plane, indicating unique differences within the 20-minute exposure groups and differences from all other groups. The 20-minute time trial corroborates the results of the first experiment. The 20- and 40-minute null groups are clustered near each other in the LDA plane, showing similarity with each other, which is expected. The 40-minute exposure OH and EXT groups show some overlap with each other, and cluster near the 80-minute exposure groups. The 60-minute null group cells were observed to be yellow in color in a pile on the slide that was denser than the other samples, unable to be usefully scanned without fluorescence. The 60-minute exposure OH and EXT groups were also observed to be yellow, while the other time groups were colored white on the slides and were able to be scanned. Both 60-minute groups seem to be an outlier, clustering on the far left side of the LDA plane. The 80-minute null group appears lower in the LDA plane, with the EXT and OH groups clustered tightly together, but on opposite sides of the 80-minute null group, indicating a clear difference between the three 80-minute groups.

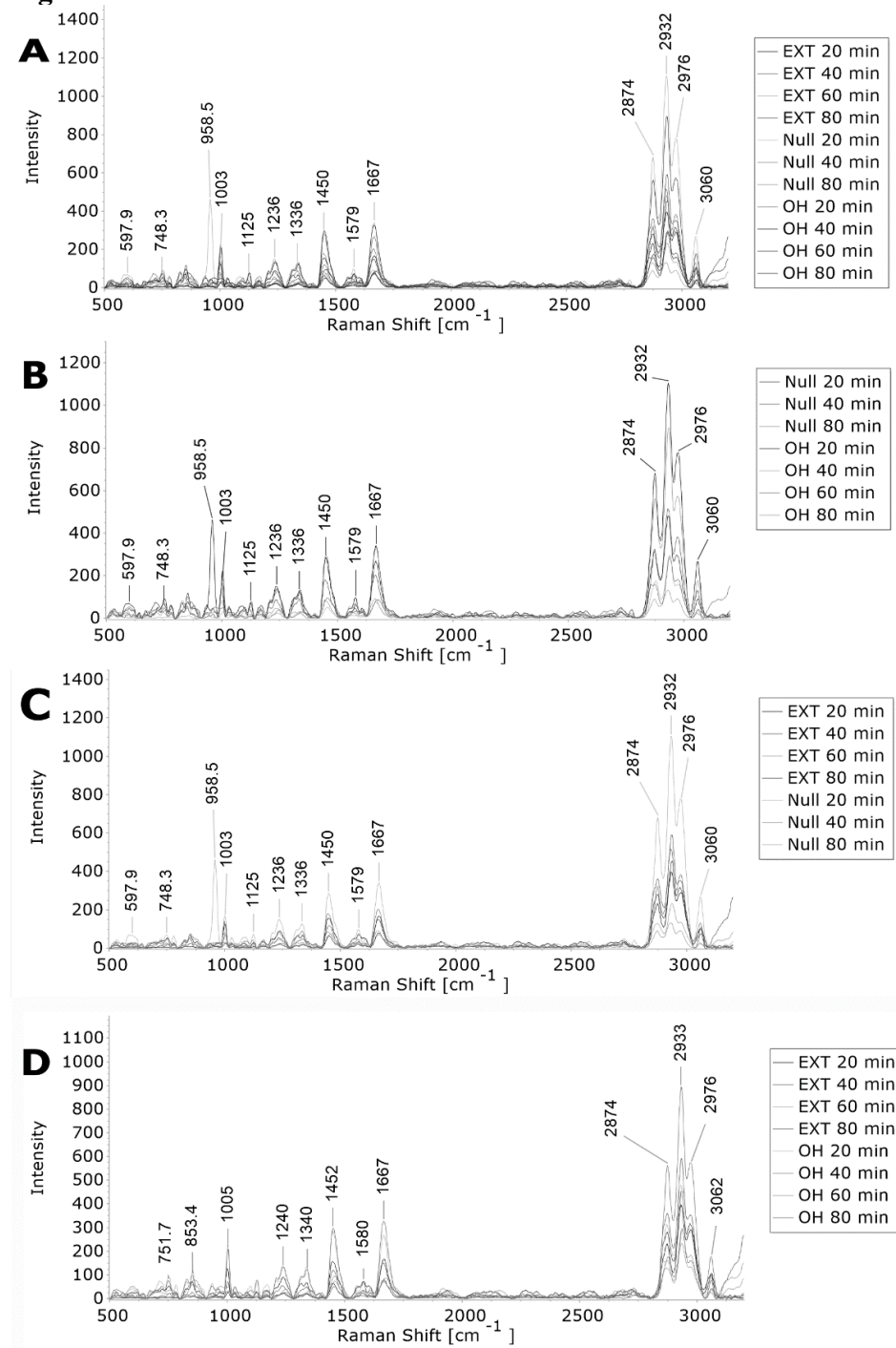
Figure 5.

Figure 5 is the collection of MCF-7 cell Raman spectra gathered using a 532 nm laser, 50x objective, and the smallest hole setting for 8 captures using 20 second exposure for 15 scans of each sample. Sample spectra were baselined, smoothed, and merged in Spectragryph software. Each plot shows the average group spectra plots with axis Raman shifted wavelength (cm^{-1}) by intensity of signal for the null, ethanol solvent (OH) and *M. uniflora* extract (EXT) groups at each time exposure (panel A), null and OH groups at each time in panel B, EXT and null in panel C, and EXT and OH groups in panel D. All spectra share nearly the same significant peaks, with

the 20-minute null group introducing a single peak at 958.5 cm^{-1} .

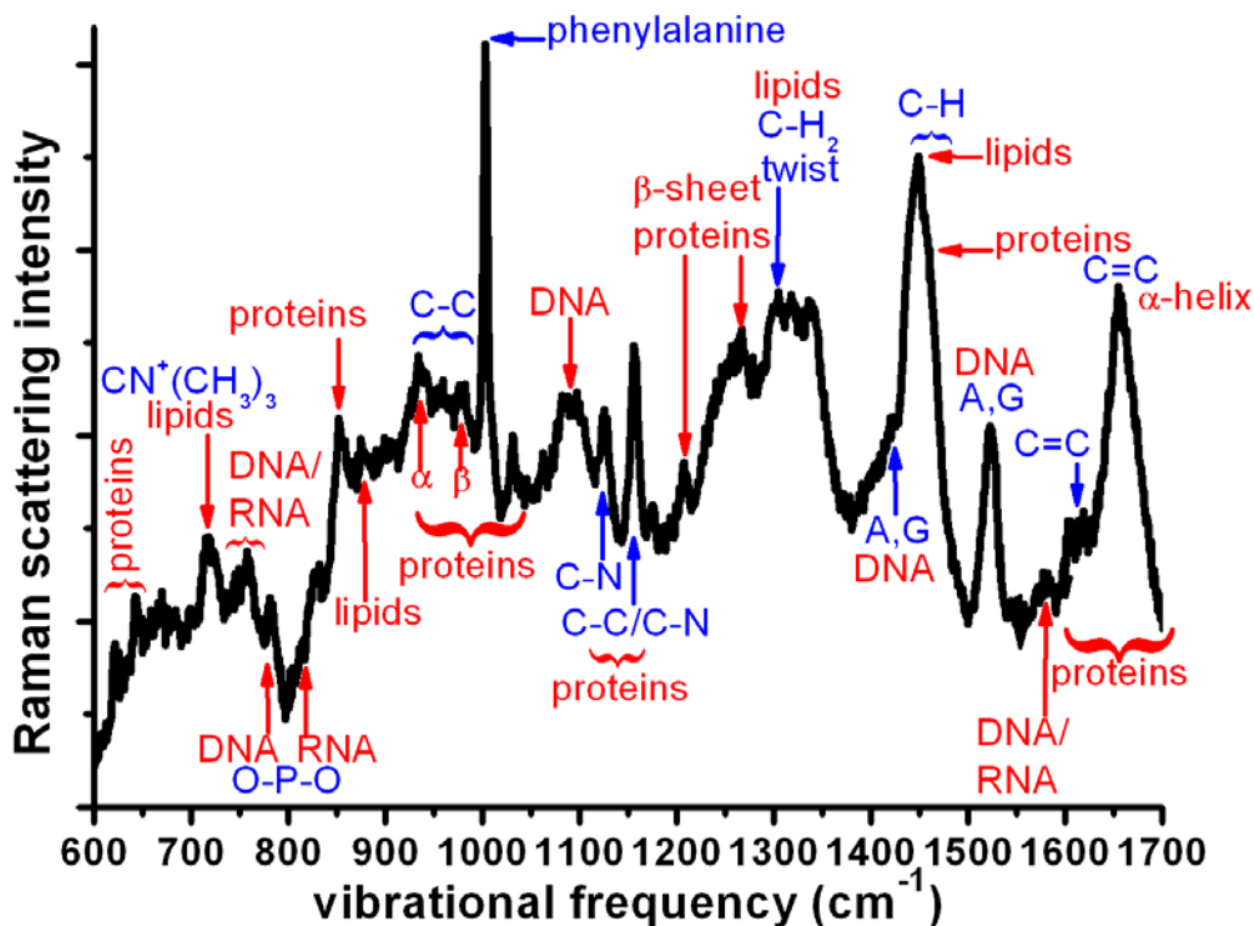


Figure 6.

Figure 6. 'Unprocessed Raman spectrum of live MCF-7 breast cancer cells. 300 seconds acquisition time, 785 nm illumination, approximately 100 mW illumination power.' (Downes A, & Elfick A. Raman Spectroscopy and Related Techniques in Biomedicine. *Sensors* (Basel, Switzerland). 2010. doi:10. 1871-89. 10.3390/s100301871.) Figure 6 highlights the specific bond stretches identified by each peak from wave numbers 600-1700.

Discussion

Comparison between figures 5 and 6 shows similar peaks of interest between $600\text{-}1700\text{ cm}^{-1}$, evidence of which bond stretches identify MCF-7 cells specifically. The spectra represented by figure 5 and passed through PCA/LDA of experiment one and two indicate some active ingredient affecting the MCF-7 cells beyond the alcohol solvent. The identity of this active ingredient remains to be tested by comparing MCF-7 cells dosed with GTX standard and *M. uniflora* extract as the next steps.

Questions about the safety of using *M. uniflora* extract as a medicine are a large motivator for

this study, especially compared to the use of other traditional medicines like Rhododendron honey. While Rhododendron honey will cause people to seek emergency medical care in the event of an overdose, there have been little to no reports of hospitalization or anecdotal stories of hospitalization from people taking the *M. uniflora* extract, as seen on YouTube or as written in homeopathic and naturopathic circles. Another point of safety stems from the fact that *M. uniflora* parasitizes mycelium, which can sequester heavy metals therefore creating a possibility that the mycelium can transfer heavy metals to the aerial parts of *M. uniflora*. This would cause the extract to have unsafe levels of heavy metals. A preliminary analysis using microwave plasma atomic mass emission (MP-AES) tested for the presence of lead in the *M. uniflora* tincture. The MP-AES results found 1,800 ppb of lead in the tincture, 120 times the amount of lead allowed in drinking water. The possible sources of lead in the tincture can lead to an exploration of if or how the mycelium transfers lead, and if the presence of lead was due to where the *M. uniflora* specimens were harvested from.

If *M. uniflora* is confirmed to produce GTX like Rhododendrons, then the safety of taking a neurotoxin which has yet to be thoroughly studied is questionable. Current studies on the efficacy and tissue effect of GTX are animal studies which largely focus on organ specific effects of GTX (27,28,29). Animal studies show cell hemorrhage, shedding, and irregular placement local to GTX injection sites. This leads to significantly higher instances of cell apoptosis for tissue acutely exposed to GTX compared to the control group, with the chronically exposed groups having far higher instances of apoptosis than the acute and control groups (28).

If *M. uniflora* does indeed produce GTX, then there are many people who are taking a risk when consuming the tincture beyond possible heavy metal contamination. The hospitals in the United States of America are not used to seeing patients taking Rhododendron honey, and if more people take *M. uniflora* due to the influence of herbalism books and YouTube videos, then there could be issues with treatments for patients who overdose on *M. uniflora* tincture.

Acknowledgements

This study was funded by the University of Wisconsin – Eau Claire using Blugold Commitment Differential Tuition funds. We would like to thank the Department of Materials Science and Biomedical Engineering for access to equipment used in the study. We would also like to thank Dr. Laurel McEllistrem and Dr. Anthony Wagner for their assistance with the Raman spectroscopy system. A special thanks to Dr. Annabel Renwick and the Sarah P. Duke Gardens for donating Rhododendron leaves to continue this study.

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Feasibility of Virtual Exercise Intervention on Occupational Fatigue, Perceived Burnout, and Daily Sleep Time Among Family Medicine Residents

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Abstract

Introduction: A career in medicine is a job of demanding hours by sacrificing one's own needs, causing an increase in mental fatigue and burnout syndrome. The purpose of this study was to examine the impact of a short-term tailored virtual exercise intervention on occupation-related fatigue, perceived burnout levels, and daily sleep time among family medicine residents.

Methods: Thirteen participants were recruited and asked to complete two questionnaires related to occupational fatigue and perceived burnout level. They were then asked to wear three monitoring devices (thigh, hip, and wrist) for fourteen consecutive days (one-week overnight shifts and another week of non-overnight shifts). Based on the feedback gained during a virtual interview with each participant on current exercise habits and perceived exercise barriers, a three-week tailored exercise program was developed, and videoclips demonstrating the exercises were prerecorded. During the second and third weeks of the intervention period, participants were asked to wear the three devices. Post-intervention questionnaires on fatigue and burnout were completed. Paired sample t-tests were employed to examine the changes in outcome variables from baseline to during intervention. **Results:** One participant withdrew from the study due to injury; therefore, 12 participants were included in the analyses. Total sleep time was higher during day shifts compared to night shifts for both baseline and intervention periods. In relation, there was a significant decrease in chronic fatigue from baseline to during-intervention. Acute fatigue and inter-shift recovery improved from baseline to intervention, but not statistically significant. A result of the three-week intervention showed chronic fatigue significantly decreased from baseline to during-intervention ($p < .05$). Acute fatigue and inter-shift recovery slightly improved from baseline to intervention but did not show a statistically significant difference. No significant changes were seen in three subscales of the burnout inventory. Daily sleep time was also higher during day shifts than night shifts for baseline and intervention periods ($p < .05$). **Conclusion:** Longer intervention period with a larger sample size is warranted to explore the effectiveness of the virtual exercise program on family medicine residents' perceived burnout, sleep patterns, sedentary behavior, and physical activity levels.

Introduction

The sufficient care given by healthcare workers is greatly impacted by the physical and psychological well-being of the employees themselves. The term burnout is defined as a psychological syndrome in response to chronic interpersonal stressors from workplace

demands associated with emotional exhaustion, depersonalization, and diminished personal accomplishment (Maslach & Leiter, 2016). Those who work as medicine residents are at a higher risk for burnout relative to the longer work hours, increased stress levels, sleep deprivation, and lack of leisure time during residency training (Baer et al., 2017). Once in existence, burnout can persistently continue throughout the residency (Campbell et al., 2010; Pantaleoni et al., 2014). A national study showed physicians were more likely to develop symptoms of burnout and be discontent with their work-life balance (Shanafelt et al., 2012). Prior literature has mainly focused on internal medicine and surgery with no specific studies showing a relationship between burnout and self-reported attitudes and behaviors (Baer et al., 2017).

Current research shows little information on specific exercise intervention strategies for reducing burnout and occupational fatigue in medical residents. Organizations are able to utilize strategies for the workplace to address burnout by altering work hours, changing workload, modifying work tasks and providing educational knowledge pertaining to burnout, wellness, and management of stress (Ishak et al., 2009). A study completed by Kancherla found that by acknowledging hours, responsibility, and central role of sleep contributing to burnout was an essential part of helping a physician's work life. It also stated sleep deprivation was a main risk factor for burnout occurring from night shifts, clinical clerkship, on-call, prolonged work hours, moonlighting (staying awake in the night), and inadequate recovery (Kancherla, et al., 2020).

Prior research showed a significant decrease in reported acute fatigue and an increase in sleep quality among the nursing-assisted personnel following the implementation of fatigue management strategies. In a study focusing on burnout, medical staff evaluated on one of the four intervention units reported a significant increase in inter-shift recovery and an improvement in sleep quality following the implementation of fatigue management strategies (Seaman et al., 2015). According to van Vandeloo et al., Dutch medicine residents who had 12 shift hours less than the Belgian medicine residents reported a lower prevalence of burnout syndrome. This type of learning environment increases the risk of developing burnout syndrome among residents with high educational demands and a lack of autonomy. Results of this study showed medicine residents in all specialties presented a high prevalence of burnout syndrome, and their psychological condition continued to arise from a continued response to chronic interpersonal stressors while at work. It was also shown that the clinical clerkship included schedule changes every 4–8 weeks leading to a shift change in hours of the day of time was also a factor in burnout syndrome (van Vandeloo et al., 2018). A career in medicine is a job with high demand hours that require individuals to sacrifice their own needs. Therefore, it is important to decrease the possibility of mental fatigue and burnout syndrome. By understanding the relationship between sleep patterns and mental fatigue, residents can assimilate their personal needs to do their job as medical professionals safely and effectively. The strenuous lifestyle of a resident can impact their quality of life, patient care, and performance as medical health professionals. Current research does not pertain to a virtual exercise intervention on the burnout out and mental fatigue on family medicine residents, allowing this study to work towards filling that gap.

The purpose of this study is to analyze the relationship between a short-term, tailored virtual exercise intervention, as well as occupation-related fatigue, perceived burnout levels, and daily sleep time for family medicine residents. Sleep variables will also be measured to analyze an association with mental fatigue levels. This study aims to replicate statistics in a

clinical health system to help further understand and explore effective intervention strategies to manage burnout and mental fatigue. There were two main hypotheses in this study: 1) chronic fatigue, acute fatigue, and inter-shift recovery will improve after the three-week virtual exercise intervention among family medicine residents, 2) perceived burnout level will decrease after the three-week virtual exercise intervention among family medicine residents.

Methods

Participants

A total of 15 family medicine residents were recruited through email and virtual meetings. Five residents were employed and were from first-, second-, and third-year cohorts at the Mayo Clinic Health System. All participants were required to have a fundamental knowledge of technology to access the virtual workout program and Qualtrics surveys. Prior to their participation, 13 participants signed an informed consent form. This study was approved by the Mayo Clinic Institutional Review Board.

Instrumentation

Sleep and Posture

The device used to categorize sleep and posture is called activPAL (PAL Technologies Ltd., Glasgow, Scotland). The version PALConnect Version 8.12.6.118 was primarily utilized for initiating and downloading data while the PALanalysis version 8.11.8.75 was used for the CREA algorithm 1.3 to analyze the data collected. The activPAL device contained an inclinometer device used to sense mixed postural shifts such as sitting, lying down, or standing. This device was also used for collecting variables related to sleep duration and the number of horizontal shifts each night. Participants were instructed to wear the activPAL device on the anterior mid-thigh of the non-dominant leg with a medical-grade 3M Tegaderm adhesive. The activPAL device was worn concurrently with the ActiGraph device during pre- and post-intervention periods and was advised to be taken off only for bathing or water-related activities. The activPAL device reliability has been found to be in an ICC range of 0.78-0.99 during a classification intervention ($p < .05$) (Lyden et al., 2018).

Sleep, Postures, and Physical Activity

The ActiGraph (ActiGraph LLC, Pensacola, FL, USA) was a device used to measure physical activity, intensity-specific, postural behaviors, and sleep characteristics of participants. ActiLife 6 software Version 6.13.4 and ActiGraph wGT3X-bt were used to gather specific variables such as frequency of exercise, intensity-specific, exercise duration, and time spent sitting, lying down, or standing. Other variables measured during sleep duration were total sleep time, total time in bed, number of disruptions per night, and the average length of disruptions made during sleep time. Participants were instructed to wear the ActiGraph device on the right wrist concurrently with the activPAL device during the two monitored periods and were advised to be taken off only for bathing or activities involving water. The ActiGraph device reliability has been found to be an ICC value of 0.99 (McClain et al.,).

Occupational Fatigue and Inter-shift Recovery

Online surveys were given to participants to ensure contactless interaction concerning

their burnout and mental fatigue. An online format Qualtrics was used to acquire responses regarding basic demographic information including age, cisgender, date of birth, year of residency, height in centimeters, waist circumference in centimeters, weight in pounds, and their declared dominant hand. Pre-intervention participants were asked to complete an online questionnaire related to occupational fatigue called Occupational Fatigue Exhaustion Recovery Scale (OFER 15). The OFER 15 measured variables on three subscales of mental fatigue such as acute fatigue, chronic fatigue, and inter-shift recovery (Winwood et al., 2005).

Perceived Burnout Level

The Maslach Burnout Inventory (MBI) measured emotional exhaustion, depersonalization, and personal accomplishment; all of which were three subscales of burnout. The MBI has been utilized in over 90% of studies focusing on burnout and has generally been regarded as a classification tool that appoints individuals to categories of burnout instead of a calculated point system for the burnout continuum (Shi et al., 2019). Participants were given a visual analogue scale that measured their mental fatigue level every day during the two monitoring periods.

Study Procedure

All participants were assigned an ID number for classification purposes that allowed them to be nonidentifiable throughout the study. Over a 6-month period, participants were individually going through their two monitoring periods based on their own schedule and availability, therefore, all participants were not going through the data collection process simultaneously. Each participant went through the same procedures beginning with two Qualtrics surveys: the Maslach Burnout Inventory and the Occupational Fatigue Exhaustion Recovery 15. Prepped and given to them at the start of their process was a bag with materials such as 14 days of log sheets, 30 Tegaderms, device application instructions, ActiGraph device, and an activPAL device in protected lining. The Wednesday prior to their scheduled monitoring period, the bag of materials was dropped off and picked up at the family medicine reception desk within the Mayo Clinic Luther campus. Data collection was scheduled to begin at midnight on Sunday when participants were instructed to place both devices on the designated part of their body before bed. Starting at midnight, the device was programmed to begin monitoring for 14 days. One week of monitoring occurred during overnight inpatient work shifts and another week during non-overnight shifts for a baseline. After 14 days of collecting data, participants were interviewed by the principal investigator to better understand the resident's time availability, lifestyle habits, exercise preferences, and perceived exercise barriers. In response to their worn devices and interviews, a three-week tailored exercise program was developed and tailored to each individual. Participants were given a prerecorded tutorial for each exercise in their program. After the three-week exercise intervention, participants were once again given the MBI and OFER 15 questionnaires. To show our gratitude, participants received a YETI Water Bottle and were provided with a summary of the results.

Data Analysis

This study design was a complex, experimental study because of the cause-and-effect relationship between exercise intervention and burnout, mental fatigue, and sleep disruptions. A one-group pretest-posttest design was employed when comparing results from baseline activity

and sleep monitoring and the third week of intervention monitoring. Given the pre- and post-intervention comparison, a paired sample t-test was utilized within the study. All monitoring information from the Actigraph and activPAL device was uploaded and stored onto Microsoft Excel where each participant's data had their own spreadsheet. Calculating the MBI responses was based on a 7-point likert scale reflecting 22 given statements. All questions were divided into three subscales of categories regarding burnout: emotional exhaustion, depersonalization, and personal accomplishment. To calculate the OFER 15 responses, scores were received from a 7-point Likert scale from the level of agreement participants chose based on 15 statements. All questions were divided into three subscales of mental fatigue: acute fatigue, chronic fatigue, and inter-shift recovery. To compare baseline and intervention results, a paired sample t-test was utilized to calculate the totals from both the MBI and OFER 15 questionnaires. The statistical significance was set at ($p < 0.05$) where data and tests were run through the IBM Statistical Package of Social Sciences (SPSS) version 28.

Results

Of the 15 volunteers contacted, 13 volunteers signed the consent form prior to the start of the study. One of the 13 participants withdrew from the study due to injury, therefore, 12 participants went through the full study ($n=12$). One participant had inaccurate activPAL data for both baseline and intervention monitoring periods and was excluded from the data analysis. There were three additional participants that contained inaccurate activPAL data for the intervention monitoring period, therefore, excluded from the paired samples t-tests involving intervention data. Participants' data were considered in the study if they had four days of valid and consistent data within a monitoring period. The devices needed to record at least twenty hours of data each day to be considered valid (Dowd et al., 2012). All 12 participants were female with four participants apart from each residency program year. The ages of participants ranged from 27-41 with an average age of 31 years old \pm 3.95 years.

Paired Sample T-Tests

A series of eight different paired sample t-tests were run using an alpha level of .05. The first paired sample t-test indicated daily sleep time obtained from the activPAL device during baseline night shifts was significantly less than daily sleep time during baseline day shifts, $t(9) = -2.88$, $p = .018$. The second paired sample t-test indicated daily sleep time obtained from activPAL during intervention night shifts was not significantly different from daily sleep time during intervention day shifts, $t(6) = -0.36$, $p = .729$. The third paired sample t-test compared baseline night shift daily sleep time to intervention night shift daily sleep time, and showed there was no significant difference, $t(7) = -0.60$, $p = .566$. The fourth paired sample t-test compared baseline day shift daily sleep time to intervention day shift daily sleep time and showed there was no significant difference, $t(6) = 1.01$, $p = .351$. Refer to Table I for descriptive statistics; daily sleep time by shift type and time (Baseline vs. During-Intervention). The fifth paired sample t-test indicated the number of awakenings obtained from ActiGraph wrist device during baseline night shifts was significantly less than the number of awakenings recorded during baseline day shifts, $t(8) = -2.68$, $p = .028$. The sixth paired sample t-test indicated the number of awakenings obtained from ActiGraph wrist device during intervention night shifts was significantly less than

the number of awakenings recorded during intervention day shifts, $t(8) = -2.59$, $p = .032$. The seventh paired sample t-test indicated the number of awakenings obtained from ActiGraph wrist device during baseline night shifts was not significantly different than the number of awakenings recorded during intervention night shifts, $t(8) = 1.19$, $p = .269$. The eighth paired sample t-test indicated the number of awakenings obtained from ActiGraph wrist device during baseline day shifts was not significantly different than the number of awakenings recording intervention day shifts, $t(8) = -0.07$, $p = .947$. Refer to Table 1 for descriptive statistics of the number of awakenings by shift type and time (Baseline vs. During-Intervention). Refer to Figure 1 for a bar graph with error bars displaying measured variables on three categories of mental fatigue such as acute fatigue, chronic fatigue, and inter-shift recovery. Figure 2 is a bar graph with error bars displaying measured variables on three subscales of burnout measuring sleep patterns emotional exhaustion, depersonalization, personal accomplishments.

Burnout and Fatigue Questionnaires

The Maslach Burnout Inventory (MBI) and Occupational Fatigue Exhaustion Recovery (OFER 15) were questionnaires given to participants pre- and post-intervention. The emotional exhaustion, depersonalization, and personal accomplishment category for the MBI was found to have no significant change from pre- to post-intervention period. Of the OFER 15 questionnaire, acute fatigue and inter-shift recovery were categories that did not show a significant difference from pre- to post-intervention as well. The main significant change seen was chronic fatigue, showing a significant difference from pre- to post-intervention.

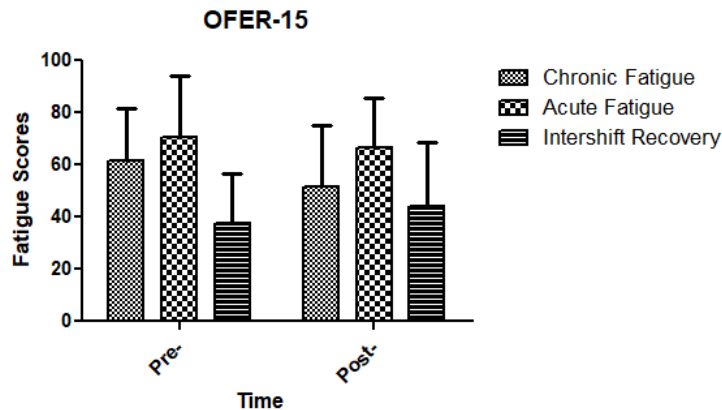
Table 1

Descriptive Statistics for Total Sleep Time and Numbers of Awakenings by Time and Shift

	Baseline		Intervention	
	Night Shift	Day Shift	Night Shift	Day Shift
Daily Sleep Time (hours)	8.51 ± 0.94*	9.45 ± 1.62	8.86 ± 1.56	9.08 ± 1.62
Number of Awakenings	14.28 ± 4.83*	16.85 ± 5.26	12.97 ± 5.02*	16.92 ± 7.10

Note: Values are presented in mean ± standard deviation. Total sleep time was obtained from activPAL devices, and number of awakenings were obtained from ActiGraph devices worn at the wrist.

*($p < 0.05$) indicates significant difference compared to day shift

Figure 1**Figure 2**

Discussion

As previously stated, sleep deprivation was a key risk factor for burnout in healthcare professionals. In a cross-sectional study focusing on the relationship of fatigue and work schedules, it was found that nurses who felt refreshed had experienced less chronic fatigue, acute fatigue, and had a higher recovery. It was also found that nurses who slept more than seven hours at a time had a higher recovery response (Sagherian et al., 2020).

Chronic Fatigue

The chronic fatigue category showed participants' levels decrease significantly from baseline to during-intervention after the tailored exercise program. While there were no

statistically significant changes for acute fatigue and inter-shift recovery, there were slight improvements in both post-interventions. Prior research looking at exercise therapy in persons with burnout concluded it could not support the theory that exercise lowered symptoms of burnout (Ochental et al., 2018). Confound variables that affected both acute fatigue and inter-shift recovery were personal health habits and weekly completion of exercises. Results from this study showed that a three-week exercise program helped decrease chronic fatigue for participants. According to a previous study focusing on burnout during residency training, an intervention for nursing staff was completed where they implemented duty-free breaks, and limited consecutive hours and shifts for a 12-week rotation period. Post-intervention results for this study showed no significant results in sleep quality (Seaman et al. 2015). The study included statistics regarding the number of awakenings and total hours of sleep per day but did not specifically look at sleep quality. The influence of quality in the OFER-15 subscales is important to refinement due to the limit of three categories and needs to be addressed further for future studies. Various levels of stress hormones, such as cortisone or nor-adrenalin, could be another factor associated with changes in chronic fatigue results (Winwood et al., 2005).

Sleep Patterns

Using activPAL inclinometers, there was significantly less daily sleep time measured for night shifts compared to day shifts, although, there was no significant difference in sleep time for night shifts and day shifts during the intervention. These results convey the liability of change in healthcare night shifts and any stressors faced during work hours. Comparing night and day shift daily sleep time between baseline and intervention showed there was not a significant difference for either shift period. There was a significant difference seen in daily sleep time between night shifts and day shifts during baseline, but during the intervention, the difference in sleep time declined and no longer showed significance. This could lead to a discussion of whether an exercise intervention played a part in longer sleep times, but the results displayed in Table 1 showed an increase in daily sleep time for intervention night shifts, but not day shifts. Confounds in this study could relate to a participant's lifestyle habits or current stressors.

Sleep data from the ActiGraph wrist devices were also collected to focus on the number of awakenings per night. The results indicated that night shifts had a significantly lower number of awakenings than day shifts for both baseline and intervention periods. As shown in Table 1, night shifts had a lower average sleep time compared to day shifts, therefore, allowing us to conclude that fewer hours of sleep would have fewer opportunities for awakening. When comparing night shifts to day shifts, there was no significant difference of awakenings between monitoring periods.

Strengths and Limitations

Although there are few studies published on activPAL sleep data monitoring for medical residents, this study presents a different approach by implementing activPAL as a sleep monitoring device. Both activPAL and ActiGraph are reliable devices increasing the validity of the data that was collected and analyzed. The activPAL device itself is regarded as more dependable for accuracy when in postural activity, while the ActiGraph was more dependable in measuring intensity-specific activity. All participants worked at the same location allowing similar work conditions and stressors to be presented. Each participant was given an

individualized exercise program that fit their lifestyle habits, exercise preferences, and prior exercise barriers. ActivPAL and ActiGraph devices were worn on day and night shifts to fully capture the effects exercise intervention may present during other work shifts.

A limitation of this study included a short intervention period with a small sample size and all female participants. To address this, future studies should implement a longer intervention period with a larger sample size focusing on diversifying the gender as an all-female resident group does not reflect a representation of the medical residency program. The sample size quality was affected by one participant dropping out of the study. Another limitation of this study included a device failure affecting the accuracy of one participant's collected data for both monitoring periods, leading to their exclusion from the study. An additional three devices lacked validity in recording participants' data from the intervention monitoring period resulting in exclusion from the study. With these devices came some discrepancies in being able to differentiate sleep time from sedentary behavior due to the placement of the device. This resulted in a potential overestimation or underestimation of total sleep time captured from both the activPAL and ActiGraph device. Future research should be completed to better understand the potential of accelerometers and inclinometers in capturing sleep attributes such as total sleep time. Some participants also reported skin irritation from the Tegaderm which could have affected the placement and wear time of the device. Participants were responsible for properly wearing both devices as well as documenting non-wear times. If done inaccurately, data collected may have been adjusted, leading to an invalid monitored period. Another limitation we faced was the accountability of participants completing the virtual exercise program recorded for them. Due to no-contact rules with participants, researchers were unable to capture an exercise adherence to the program which could have affected the outcomes of the post-intervention questionnaire results. To address this, future studies should implement a virtual accountability system such as weekly check-ins, meetings, or an online format made available to residents.

Conclusion

The hypothesis that sleep disruptions will decrease when residents are on day shift and increase when they are on night shift was not supported by our results, but instead found the opposite in our findings. The results showed a decrease in chronic fatigue, showing the feasibility of a virtual exercise intervention and the potential for reducing mental fatigue and occupational burnout. If future organizations are concerned about the chronic fatigue and burnout levels of their employees, a virtual exercise program could be provided to address this matter.

Future research is needed for a standardized definition of quality sleep so that sleep pattern data from activPAL and ActiGraph can be employed properly to monitor and improve sleep quality in family medicine residents.

Acknowledgements

This study would like to acknowledge Dr. Terri Nordin for connecting researchers with Mayo Family Medicine residents and aiding in the research process. This study would also like to acknowledge Tommy Atwood, Chloe Hendrickson, Claire Hoge, Alyssa Horton, and Sasha

Pankratz for aiding in the logistics and data analysis of this project. This study would also like to acknowledge the Ronald E. McNair Program and ORSP Summer Research Grant for funding this project.

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The Rise of QAnon: From Chatroom Board to an International Movement

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Abstract

This project will investigate how online indoctrination of the conspiracy theory QAnon has led to the formation of groups and movements in an international context through time. QAnon is an overarching online conspiracy theory that has many different beliefs, including that the world is run by a Satanic cabal of pedophiles or that JFK Jr. Is still alive. This is important because the belief in the QAnon conspiracy has led to violence, both in the United States and internationally. Such events include January 6th, 2021, and the “Freedom Convoy” in Canada. Regardless of the origin, the ideas rooted in QAnon conspiracies have grown worldwide; if you have access to a computer, you are able to interact with QAnon content. The main concern surrounding QAnon is how it has co-opted a legitimate movement to push their narrative, with #savethechildren. Moreover, QAnon has given rise to and fueled similar conspiracies worldwide. We will utilize the Twitter API and the coding language python to create a model to track the spread of QAnon through time. Once we get key data points, we will cross-reference them with what was in the news at the time. This project is done to contribute to the new research of extremism online.

Literature Review

Introduction

QAnon is a family of conspiracy theories that began online. Because it is a family of theories, and not just one, there is a wealth of information surrounding QAnon that it is hard to pick just one aspect of the theory to research at a time. I specifically chose to research QAnon on Twitter because I could research how the theory became more mainstreamed. Even though the theory started on the fringes of the internet, it moved to places like Twitter and Facebook where more “normal” people could interact with it without having to go on sites like 4chan or 8kun. These sites are dangerous because they are host to various taboo and upsetting content. This content includes child pornography and antisemitic and racist rhetoric that, such as the one at a Buffalo, NY grocery store.^{1 2} The data gathered for this project was only from Twitter, which cannot give the full picture of the presence of QAnon online, but it can give us insight into the spread.

What is QAnon?

If you have been online in the past 6 years, you have probably interacted with some form of QAnon or QAnon adjacent content. This includes movements like “Stop the Steal” or #savethechildren. But what exactly is this theory? QAnon is a family of conspiracy theories

online that started on 4chan in October 2017.³ In this context, a conspiracy is defined as “alternative explanations of historical or ongoing events claiming that people or groups with sinister intentions are engaged in conspiratorial plotting,” (Mahl, Schafer, and Zeng, 2).⁴ The origins of the theory state that the world is run by a Satanic cabal of pedophiles but has broadened to distrust of all authority. 4chan is an image board that is home to fringe groups online. An anonymous poster, “Q”, posts on 4chan, and then 8chan (and its successor 8kun) are called “Q-drops”.⁵ Below is the first Q-drop that was posted on 4chan.⁶



The theory is everlasting because it migrated away from the chans and onto mainstream social media platforms like Facebook and Twitter. This migration has made QAnon dangerous. In an increasingly online society, people have stopped questioning the sources of information on the internet, and just believe what is posted is the truth. In 2020 these social media platforms recognized the danger of QAnon and started to crack down on QAnon content.⁷ This sterilization of the sites did not deter believers—it did the opposite. Their beliefs in Q became validated. That does not deter believers though, including those in the United States government such as House Representative Marjorie Taylor Greene.⁸ However, she has since backtracked on promoting QAnon beliefs while in office.⁹

Who is Q?

The QAnon conspiracy states that Q is a government insider that tells us what is going on behind the scenes. This person is an individual in the Department of Energy with “Q level” clearance.¹⁰ This clearance just means that they have access to top secret information within the United States government. Looking at the Q-drops, Q speaks with a level of authority that lends credibility to the theory that allows people to be more comfortable believing in it. There is linguistic evidence that shows that Q is not a member of the Department of Energy, but rather two individuals—Ron Watkins and Paul Furber.¹¹ Both Watkins and Furber have history with the chans. Watkins is the son of the owner of 8kun and Furber is an administrator for 8kun. Two independent research teams used a “mathematical approach called stylometry”.¹² Stylometry is the process of studying cadences and the use of certain words over others. To figure out who Q is, the two research teams compared Q drops to posts made by Watkins and Furber. The first team compared patterns in three-character sequences with vocabulary and syntax. The second team used artificial intelligence that learns an author’s writing patterns and compares it with Q drops. These two teams independently came to the same conclusion: Ron Watkins and Paul Furber are most likely behind QAnon.

Core Beliefs

One thing to keep in mind about QAnon, is that it is a family of conspiracy theories, not just one. The main themes that run through this theory includes the belief that the world is run by a satanic cabal of elite pedophiles, Donald Trump is our savior from this cabal, and that there is a “storm” coming that will take out the elites¹³ ¹⁴This cabal includes high-profile celebrities and politicians like Oprah Winfrey and Hillary Clinton.¹⁵ The theory states that former President Donald Trump is the one to save us from said satanic cabal. They also believe that the election was stolen from Donald Trump in 2020. There are some aspects of the theory that not every Q believer believes in. This includes the idea that JFK Jr. is still alive and will become Donald Trump’s vice president in 2024.¹⁶ Another branch of the QAnon theory is that JFK Jr. was assassinated by the Clinton family.¹⁷ The family tree of QAnon has fractured and twisted into something unrecognizable. Even when there is the base belief that the world is run by a cabal of satanic pedophiles, there are some aspects of the theory that don’t relate to that. The cabal includes people like Hillary Clinton and other high-profile democrats. This base fear stems from the fear of the Democratic Party being in control of politics and life around the world. The satanic pedophile part of the belief is what connects the branches of the theory together—what reconciles the fear mongering between Hillary Clinton and the rest of the world.

History of Internet Culture

To comprehend how QAnon evolved, there needs to be an understanding of the history of internet culture, especially surrounding the chans. The chans are online image and text boards that started in Japan in the late 1990s.¹⁸ They were a place of solace for the more fringe groups of Japanese culture. In the early 2000s, the interest in Japanese subculture exploded into other areas of the world, including the United States. More people flocked to 2chan to interact with this content, as its interest in Japan and its culture was becoming more prominent. 2chan is the original iteration of the chans.

4chan was created by Chris Poole who went by the name “moot” in early October of 2003.¹⁹ Poole says that he created 4chan because “I was very bored, in need of porno, and wanted a cool email address... The immediate result was a cool 2chan clone that provided me with all such things, but a few unwanted side effects.”²⁰ 4chan was meant to just be another 2chan— a place to talk about anime without repercussions. But as it evolved, it ended up succumbing to anons, trolls, and hackers. It was common for people to “shit-post” —posting something as a joke, not to be taken seriously— and “LARPing” or Live Action Role Playing. Memes were a large part of shit-posting. But 4chan is a double-edged sword. While there were people messing around on the site, there was a very real threat of people believing in the posts and subsequently acting on them. An example of a post would be what It is not uncommon for those on 4chan to joke themselves into believing something, no matter how horrid. There have been multiple cases of people posting their manifestos on 4chan before committing a mass-shooting or other terrorist attack. An example of this would be Peyton Gendron posting his manifesto on 4chan before committing a mass-shooting at a grocery store in Buffalo, NY in May of 2022.²¹ Because of this, 4chan started to become more regulated. That is where 8chan comes into the picture.

8chan was created as a reaction to crackdowns on 4chan.²² The founder, Frederick Brennan, wanted 8chan to be a refuge for free speech.²³ It was less regulated than 4chan, allowing for more shit-posting, LARPing, child pornography, and being pillled into the far-right and far-left ideologies. But as 8chan became more dangerous, the servers were moved to the Philippines where it would be less regulated. It was sold to a father-son duo—the Watkins'. As mentioned before, there is linguistic data that suggests that the son, Ron Watkins, is behind QAnon. There is also evidence from the newest Q-Drops that Q had to be an 8kun administrator, or someone close to admin.²⁴

History of QAnon

One cannot discuss QAnon properly without putting it into context. Without understanding the movements that came before QAnon, one cannot grasp the complexity of it now. These movements include the Satanic Panic of the 1980's and 1990's, pizzagate, and #savethechildren. These movements all have one thing in common—moral panic surrounding the ritualistic sexual abuse of children. The Satanic Panic was a movement in the 1980s and 1990s that believed that children were being sexually abused by other adults in their lives, such as teachers, in Satanic rituals.²⁵ What is important to note is that in one case over 400 children were interviewed about this abuse and were coerced by the school and parents into giving false testimony.²⁶

Pizzagate is a conspiracy theory that came out of the WikiLeaks of Hillary Clinton's emails.²⁷ A commonality between pizzagate and QAnon is that they both started on 4chan. In these emails, Hillary Clinton and John Podesta, her campaign manager, were discussing types of pizza to order, and there was mention of "cheese pizza". What sparked the pizzagate conspiracy was that "cheese pizza" and "child pornography" share the same initials. This then led people to believe that cheese pizza was code for child pornography. An important thing to note is that there is a high possibility pizzagate started as a joke. As mentioned before, 4chan is notorious for shit-posting. What is worrying is that people do not question the credibility of 4chan and 8chan and take what is posted at face value. This also occurs when Q posts on the chans. A frustrating aspect about pizzagate is that the believers are so concerned with what the theory states that they do not, or will not, see the impact it has had on real lives. This includes the owner of Comet Ping-Pong, the pizzeria that is at the center of pizzagate. Joan Donovan, the research director of the Shorenstein Center of Media, Politics and Public Policy at the Harvard Kennedy School said, "the big difference between 2016 and pizzagate and QAnon [now] isn't the themes... it's the scale".²⁸ Essentially, QAnon is pizzagate on steroids.

A unique thing about #savethechildren is that Save the Children is a legitimate organization with the goal of protecting children around the world.²⁹ But the phrase was co-opted by QAnon. This led to #savethechildren and QAnon to be concurrent theories. At face value, #savethechildren is just about saving and protecting children from child sex trafficking—no rational person would discredit this as something bad. This ends up being harmful as people end up interacting with QAnon content without being aware. Part of the spread of QAnon is due to this hashtag.³⁰

As with any movement, the QAnon conspiracy ebbs and flows. I will discuss this more in depth in the Data Analysis portion of this paper. During the time frame of 2018 to 2021, QAnon was more popular in the years 2018 and 2020. It is worth noting that both of these years were election years, which does have some impact, but there are other aspects of those two years that need to be considered. Even though QAnon started in 2017, it was popularized in 2018. There was a dip in 2019 due to QAnon moving from 4chan to 8chan. 8chan was then taken offline as a response to the El Paso mass shooting due to the shooter posting his manifesto on 8chan.³¹ This removal on August 1st, 2019, meant that there were no new Q-drops to analyze. There was then a rise in 2020, largely due to the COVID-19 pandemic; everyone was at home and had time to be online. This is also due to 8kun going live and the return of Q-drops.

Data

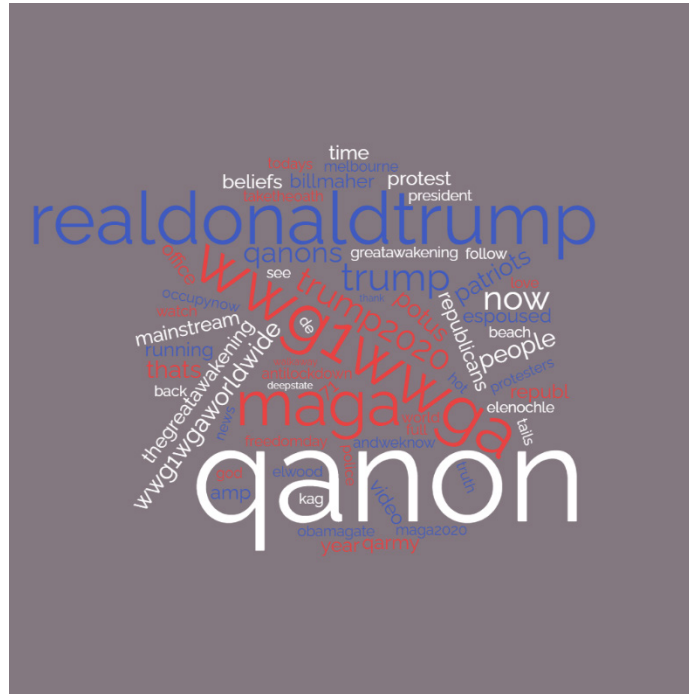
Methods

In order to track the spread of QAnon online, my research partner and I used the coding language Python and Twitter's Academic API. API stands for Application Programming Interface. Twitter has a few levels of API—Essential, Elevated, Elevated +, and Academic Research.³² The Academic API is the most expansive of the 4 as it allows full access to tweets, archived or not. This allows us to get a full picture of the spread of QAnon on Twitter. We were able to have access to all of the tweets, instead of just a sample size. Once we had access to the tweets, including those that were archived (a feature of the Academic API), we were able to web-scrape tweets. Think of web-scraping as a latte with foam on top. The coffee part of the latte is the background code, and the foam is the content that is presented to the public. What we did was scrape the foam off the top, collected the presentable content. We then web-scraped tweets that had the hashtag #WWG1WWGA and #WWG1WGA. #WWG1WGA stands for "Where We Go One, We Go All". Think of this hashtag as the calling card of QAnon. This phrase comes from the 90's movie "White Squall".³³ Other hashtags could have been used such as #thegreatawakening, #thecabal, and #qanon.

Data Accumulation

I worked with a computer science student to help me with this research. The project began by researching different ways to pull data from Twitter. There were some outdated Python packages that might have worked, but do not look at archived tweets. We needed archived tweets as well as public tweets in order to get the full picture. Archived tweets are unavailable to the general public. After gaining access to the API, documentation was read on how to configure the request with different parameters. To do this, postman was used, which listed all available Twitter endpoints to hit, as well as what parameters to use. After testing out the API via postman, a script was coded in python to make the calls and save them in a JSON file. Some problems quickly arose, as Twitter has a max request limit of 2,700 requests per 15 minutes, which equates to 1 request every 3 seconds. Additionally, the Twitter API would randomly go down for brief periods of time overnight, crashing the program and inevitably wasting time. Once all of the data was collected, a graph was made to show how many tweets occurred each day. In order to make this graph, each tweet was looped to determine if it was posted the same day as the previous tweet

or a new day. Once a CSV file was created with the date and number of tweets, excel was used to create a graph. In order to create a word cloud from this data, all emojis, punctuation, and common stop words were removed. Each word of each tweet was looped to count how many times it occurs. From there, the CSV file generated was exported to a word cloud generating site. Below is an example of the world cloud, done with the typo that was made.



Limitations

As with any research project, there are limitations. Right now, Twitter is very unstable, and the type of research I am conducting can easily go sideways.³⁴ I might not be able to do research exactly like this in the future. There is also a large amount of information on QAnon, from the different aspects of the theory to “proto-QAnon”. Also, because QAnon has become an international movement, any tweet that we pulled with #WWG1WGA could be in any language. I only analyzed in depth tweets that were in English. Another thing that puts limits on this research is that QAnon is still *very* prevalent in the news.³⁵ Research into it can be done in any time frame from 2017 to present. I had to narrow the time frame to something that would give me the broad picture of the spread of QAnon, but not so narrow where I could not analyze the trends through time.

Doing research on Twitter is also challenging, especially when researching something within politics. This is because bots (robots or automated profiles) post a lot to flood the hashtag to artificially increase the number of tweets. The number of tweets could also be inflated because of the sheer number of retweets. However, in order to track the spread of QAnon online, it is important to include the number of retweets in the data. A retweet allows for the information to get out to that profile's audience and not just the original posters.

Data Analysis

The data collected from web-scraping was put into an Excel file where a line graph was then made to show the frequency of #WWG1WGA and #WWG1WWGA. I included the typo into this table to show that there was also a trend, albeit small, in the frequency of said typo.. There is also a table just for #WWG1WGA which shows the frequency of #WWG1WGA over time. These tables are used to show the overall trend of both hashtags.

I also made tables for each year with the number of tweets per key dates. The dates selected were chosen from a timeline of Q-drops done by Edward Tian for Bellingcat.³⁶ Bellingcat is an investigative journalism website. He categorized Q-drops by important events in the news as well as the number of Q-drops per section of time. I separated the analysis of each time frame according to the timeline that Tian provided as it gives a broad perspective as to what mattered to the QAnon conspiracy. Within each of the time frames provided, a maximum of three dates were chosen to analyze. I also looked at the trends between months. An example of this would be looking at the number of tweets posted in March 2018 and May 2018 and then analyzing the transition between the two months—what happened in American politics that made QAnon more popular? In the Q-drops? From August 1st to November 11th of each year, I created a line graph to see if there was any significant impact on the number of tweets, even when Q had stopped posting on 8kun. This is because in 2019, 8chan was taken down. Q had already migrated from 4chan to 8chan. Q started posting again on November 11th, 2019.

2018

Timeframe	Date	Number of Tweets
January–March 2018	3/31/2018	71
January–March 2018	3/13/2018	4
January–March 2018	2/26/2018	3
April–May 2018	5/11/2018	1,882
April–May 2018	5/8/2018	1,873
April –May 2018	5/20/2018	1,843
June–July 2018	6/25/2018	3,316
June–July 2018	7/25/2018	2,942
June–July 2018	7/31/2018	2,822
August–September 2018	8/2/2018	4,007
August–September 2018	9/18/2018	3,993
August–September 2018	8/1/2018	3,834
October–December 2018	11/6/2018	5,052
October–December 2018	11/4/2018	3,636
October–December 2018	11/5/2018	3,399

QAnon started to become more popular on Twitter in 2018. It wasn't until the end of March, however, that there were a significant number of tweets. On March 31st there were 71 tweets. This was a time period where Q was posting about the Obama administration and claiming that they aided Iran and North Korea by sending them technology. There were also posts about Russian interference in the 2016 presidential election. QAnon grew as a movement and by mid-May there were thousands of #WWG1WGA tweets posted, for example, on May 11th with 1,882 tweets. The popularity of QAnon consistently increased from May to the summer and fall months. In 2018, the day with the greatest number of tweets was the day of the Midterm Election, November 6th when there was a total of 5,052 tweets posted.

2019

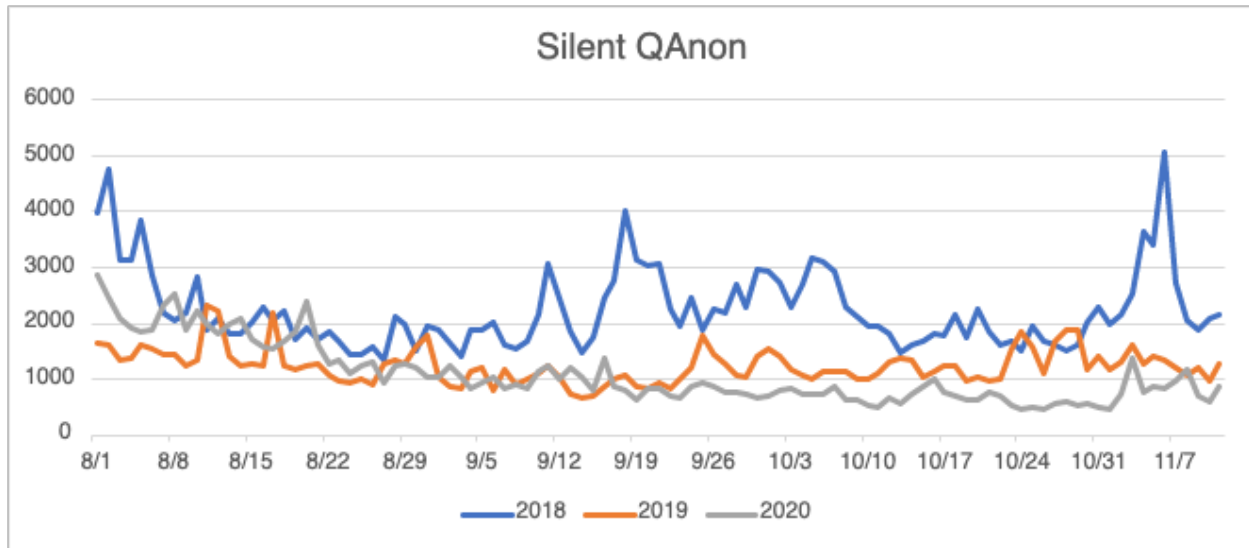
Timeframe	Date	Number of Tweets
January–March 2019	3/28/2019	6,825
January–March 2019	3/29/2019	4,389
January–March 2019	3/10/2019	4,043
April–June 2019	5/24/2019	2,198
April–June 2019	4/11/2019	1,821
April–June 2019	4/14/2019	1,790
July–August 1 st 2019	7/12/2019	4,036
July–August 1 st 2019	7/18/2019	3,887
July–August 1 st 2019	7/30/2019	2,640
August 2 nd –November 10 th 2019	8/11/2019	2,317
August 2 nd –November 10 th 2019	8/12/2019	2,207
August 2 nd –November 10 th 2019	8/17/2019	2,182
November 11 th –December 2019	12/19/2019	2,509
November 11 th –December 2019	12/28/2019	2,467
November 11 th –December 2019	12/4/2019	2,062

QAnon was still going strong in 2019 until August 1st, 2019. Q had already moved from posting on 4chan to 8chan. This movement ended up being detrimental because 8chan was taken down on August 1st. From August 1st to November 10th, there were no new Q-drops. There is a significant dip in the number of tweets posted in that timeframe. The top three days within the timeframe of August 1st to November 10th are in the middle of August. The frequency of tweets dipped into the low 1,000s during that time. This could mean that because Q was not posting, people were not getting new content to push the theory.

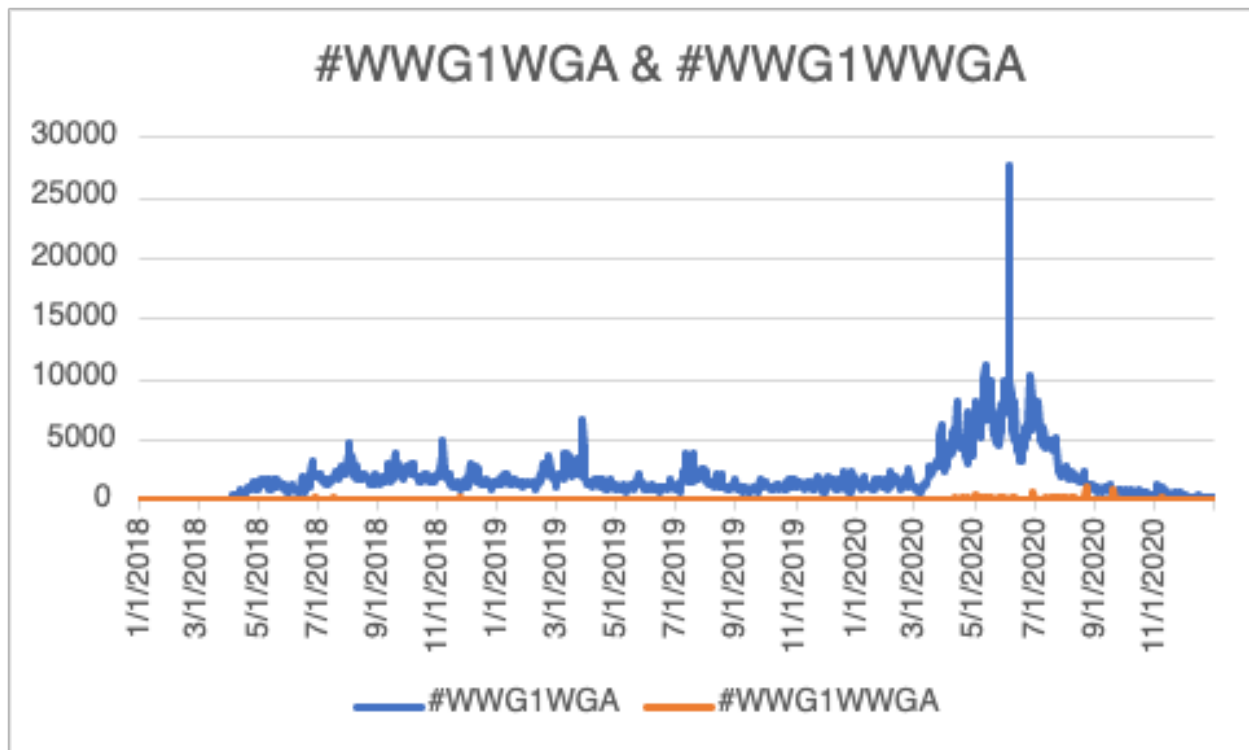
2020

Timeframe	Date	Number of Tweets
January–April 2020	4/12/2020	8,182
January–April 2020	4/14/2020	7,494
January–April 2020	4/24/2020	7,349
May–July 2020	6/5/2020	27,821
May–July 2020	5/11/2020	11,214
May–July 2020	6/27/2020	10,478
August–September 2020	8/1/2020	2,859
August–September 2020	8/8/2020	2,541
August–September 2020	8/2/2020	2,446
October 2020	10/16/2020	1,017
October 2020	10/7/2020	857
October 2020	10/15/2020	855
November–December 2020	11/3/2020	1,365
November–December 2020	11/8/2020	1,163
November–December 2020	11/7/2020	983

The year 2020 brought a number of large events, including the COVID-19 pandemic, the murder of George Floyd, and subsequent protests. From January 2020 to April 2020, the top three dates of tweets posted were all in April. This was the height of the COVID-19 lockdown and anti-mask sentiment. Many people who believed in the QAnon conspiracy also bought into anti-COVID-19 conspiracies. On June 5th, 2020, the largest number of tweets within all three years peaked with 27,821 tweets. The Black Lives Matter protests in response to the murder of George Floyd had become intense and led to riots. Twitter banned a large number of QAnon content creators on July 21st, 2020. This can be seen by the large dip in tweets from June to August.



This line graph represents all three years of data that was collected from August 1st to November 10th. QAnon was most popular in 2018, as seen with the blue line. On November 6th, 2018, the frequency of tweets peaked, going just above 5,000. The graphs for 2019 and 2020 look very similar in this timeframe. This was to be expected because there were outside forces interfering with the spread of the conspiracy. These outside forces include the lack of Q-drops due to 8chan being taken down the summer of 2019 and its transition into 8kun. In 2020, it was because major social media platforms removed prominent QAnon accounts, leading to a decrease in the reach of the conspiracy from those accounts.



The frequency of #WWG1WWGA did not make a strong impact on the frequency of #WWG1WGA. It was just genuine typos being made— a typo I made myself when pulling the tweets. #WWG1WWGA is inconsequential when it comes to looking at the spread of #WWG1WGA; it does add enough to affect the overall trends seen in the graph above the highest spike for #WWG1WWGA was in late summer of 2020— right when the 2020 presidential election was heating up.

Significance and Further Research

Significance

It is important to research QAnon for a multitude of reasons. QAnon has prompted violent events that include people murdering their family,³⁷ running from the police,³⁸ kidnappings,³⁹ and the January 6th insurrection on the United States Capital.⁴⁰ Because of these events, the Federal Bureau of Investigation has determined QAnon to be a domestic terrorist threat.⁴¹ QAnon is also related to other fringe groups like the Oathkeepers, the Proud Boys, and white supremacy in general.⁴² This relation is due to the racist, antisemitic, transphobic, and homophobic tropes that it plays on. Because there is this undercurrent of distrust in the government within the theory, QAnon played a big role in the anti-lockdown, anti-vaccine, and anti-mask sentiments during the early days of the COVID-19 pandemic.⁴³

This project contributes to the study of QAnon over time. While others, like Will Sommer, have done qualitative analysis of the growth and metastasizing of QAnon online, few have done a deep dive into the theory on certain websites, such as Twitter.⁴⁴ It is important to examine how the theory remained on social media sites, even after Q stopped posting, like in the summer and fall of 2019. This insight will let us know how social media sites handle conspiracy theorists and their impact on the site.

Further Research

There are multiple avenues of further research that I can pursue. I could conduct the same experiment but adjust the timeline from 2021 to 2022. This project could also be done but with different QAnon vernacular such as the “deep state”, “the great awakening”, and the “cabal”. I could also compare the depth of the theory before and after the 2020 presidential election. In doing this, I would be able to see the full effect of the election, January 6th, and the #stopthesteal movement. A similar project could also be done, but on a different social media site such as Telegram or Truth Social. I could also take a deep dive into internet subcultures, especially on 4chan, 8chan, and 8kun to gain an understanding of how conspiracy theories metastasize online. Lastly, I could potentially also research QAnon in general and its themes in our government. This includes members of our legislative branch who believe in QAnon and how that belief has affected their voting record.

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Three-State Biaryl Lactone Molecular Switches with Amine Donors

Courtney Westlund
Dr. Bart Dahl

Abstract

This project is focused on the synthesis of four bridged biphenyl molecules with amine donors. These three-state biphenyl molecules, due to their chemical properties, will find applications as nanoscale fluorescent sensors and molecular mechanical devices. Biphenyl molecules have known dihedral angles, leading to differing optical and conducting properties when manipulated. By using a lactone-bridge we can force the molecule into and out of planarity; at low pH the molecule takes a planar conformation (“ON”), while at high pH it’s non-planar (“OFF”). Research from previous groups has shown similar two-state molecules’ effectiveness at readily switching conformations when exposed to different chemical environments. We are researching the addition of diethylamine and diphenylamine donor groups. By combining previously used cyano and nitro acceptors and differing amino donors within biphenyl molecules, we can enhance optical properties and pH sensitivity. This pH sensitivity will be more precise with the addition of a third “OFF” state of the molecule. At low pH, the amino group should become protonated, leading to the second “OFF” state and giving the molecule a narrow “ON” state. The “ON” state would result in heightened visible color differences than the “OFF” state of the molecule. These characteristics would improve the usefulness of these molecules as pH sensors. Two of the target molecules, one molecule being the cyano acceptor group with diethylamine donor group and the other molecule having a nitro acceptor group and diethylamine donor group, have been successfully synthesized.

Introduction

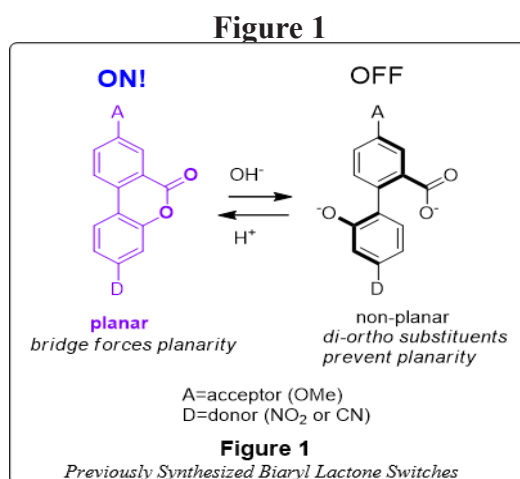
Molecular switches, which are molecules that have the ability to reversibly switch between two geometrically distinct states when exposed to outside stimuli, have recently become a popular area of study over the last few years. Due to this new interest, the possible uses for molecular switches has widely grown. The known applications for these molecular switches includes nanotechnology, biomedicine, and the design of computer chips.¹ As stated, molecular switches have the ability to reversibly switch between states and the applications rely on the controllable switching of the molecule when exposed to stimuli.² These outside stimuli can take the form of electrical current, light, magnetic fields, biological impulses, or acid-base chemistry. Our research group is interested in the biphenyl molecule and its ability to switch between a planar and non-planar state. The choice of this structure for our research stems from the dihedral angle of the aryl-aryl bond while in the planar state, which results in intermolecular

charge transfer due to the high degree of pi-orbital overlapping. Controlling the geometry of the biphenyl molecule will also allow us control of its inherent properties³, like electronic excitation, emissions, non-linear optics, conductance,⁴ and fluorescence.⁵

It has already been experimentally determined that the biphenyl conformation occurs with a twist angle of 30-40°.⁶ This angle of 30-40° reflects the steric hindrance of the hydrogens on each ring, opposing one another, and the electronic communication due to the molecule's planar system. The molecule is unable to be perfectly planar due to the hydrogens, but the electronic communication is favorable. This slight angle allows for a middle-ground, by allowing the greatest possible conjugation and relatively low steric hindrance. The dependence on angle regarding electronic communication allows the possibility of manipulation, where we control the optical properties by simply changing the angle.

The biphenyl molecule by itself cannot be controlled conformationally, meaning it would not serve as a molecular switch. By using a derivative of this biphenyl molecule, we should be able to control the angle, which would make it a candidate for a molecular switch. The different angles of the molecule, otherwise referred to as states, would result in differences of conductance and fluorescence.

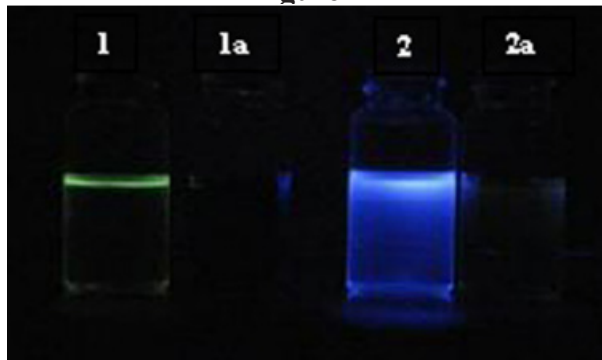
Previous work conducted by the Dahl research group resulted in the molecular switch observed in Figure 1.⁴ The control over the biphenyl angle stems from the lactone bridge connecting the rings, which can be cleaved and reformed by adding acid or base. The bridge, once formed, forced the molecule into a planar conformation. This planarity allows the greatest electronic communication due to pi-orbital overlapping.⁷ Once the bridge is cleaved, the molecule succumbs to the steric hindrance of the hydrogens, allowing the rings to revert to its non-planar state. This structure, a biphenyl molecule connected by a lactone bridge, is a blank slate in regard to what groups we could add on. The acceptor and donor groups are of interest to enhance the optical properties of the molecule, which would make it more valuable as a molecular switch.



The molecule in Figure 1 is considered a two-state molecular switch, where the molecule has one “ON” state and one “OFF” state. The “ON” state is where the lactone bridge is formed and the rotation, or angle, of the biphenyl molecule is restricted. This hindrance results in a loss of energy compared to the angled version of this molecule. The energy being lost is observed as

light being emitted and the wavelength of light is within the UV region of the spectrum. Figure 2 is an example of the previous switches synthesized,⁴ where 1 and 2 are the “ON” state and 1a and 2a are the molecule once the lactone bridge has been cleaved.

Figure 2



The two-state switches mentioned were synthesized in multiple separate reactionary steps. The starting material chosen was 2-bromobenzoic acid, which was nitrated and esterified. A Suzuki reaction and lactonization were then performed to create the biphenyl structure and close the lactone bridge. This is a relatively easy synthesis, which can theoretically be modified to produce alternative switches.

Knowing that the biphenyl molecule combined with the lactone bridge could be synthesized and reversibly controlled when exposed to acid or base, our research project aimed to expand on the structure and optical properties. By changing the acceptor and donor groups located at the top and bottom of the biphenyl rings, it was proposed that a three-state switch would be possible. This three-state switching has been performed by other successfully synthesized, albeit larger conjugated molecules, where they observed two “ON” states and one “OFF” state.⁸ This proposed change to the skeleton and properties of the molecule would make it a much more effective and useful as a molecular switch.

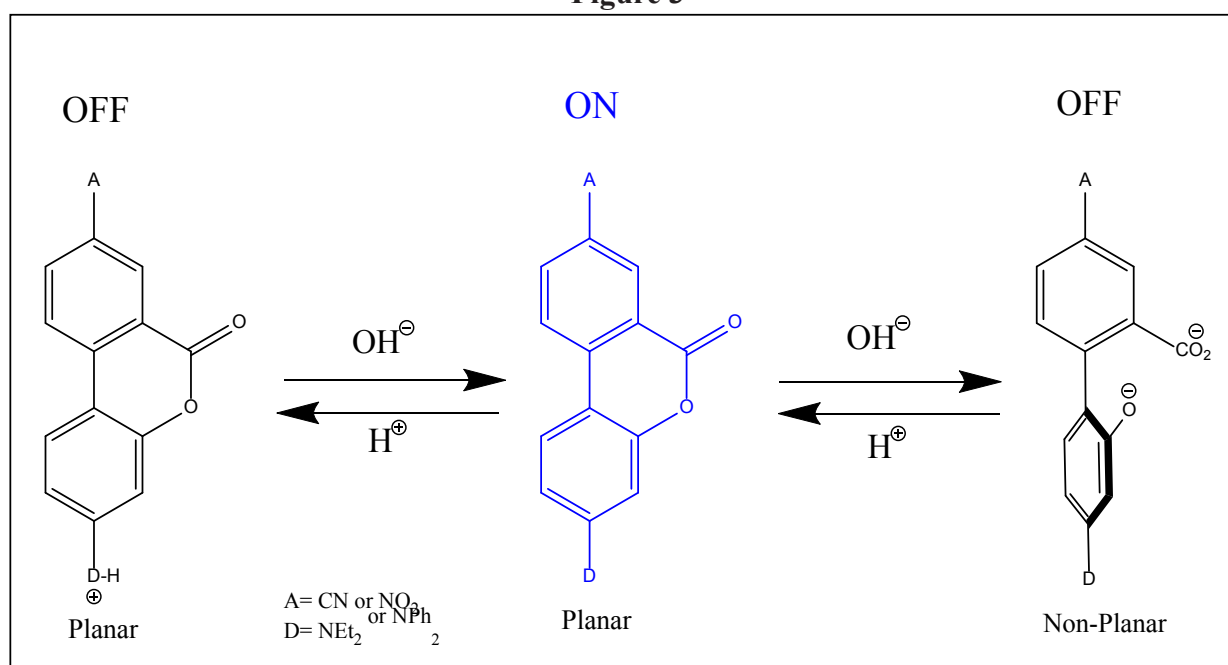
The alternative donor and acceptor groups of this molecule had to be carefully chosen in order to achieve the three-state nature of our molecules. We proposed four new three-state molecular switches with two sets of donors and acceptors combined. Initially, the donor groups of diphenylamine and dimethylamine were chosen due to their increased intermolecular charge transfer through the rings and higher basicity. Dimethylamine was later changed to diethylamine due to greater yields during synthesis, however diethylamine still serves as a very strong donor group compared to the previous two-state switch’s methoxy donor. The strength of the donor group and increased intermolecular charge transfer should correlate with the optical properties observed with the final molecules. The addition of an amine group to the molecule also allows the possibility of a third state.

The acceptor groups for the molecular switches were also chosen to alter the optical properties. The groups chosen were the nitrile and nitro acceptors. Theoretically, the nitro group should afford more color within the molecule, but it does have the ability to quench the fluorescence. So, these molecules should not be as bright. The nitrile group should be very fluorescent once synthesized but they would not be as colorful as the nitro switches. Once the donor group,

acceptor group, biphenyl rings, and lactone bridge are brought together, we should have a three-state “OFF”-“ON”-“OFF” switch. This designation shows that there is only one optically interesting state, which will increase the precision of the switch.

The “OFF”-“ON”-“OFF” states of the molecule are allowed because of the addition of the amine group onto the molecule, whether it be diethylamine or diphenylamine. The “ON” state is where the lactone bridge is intact, and the amine group is unprotonated. By adding acid to this state, we were able to protonate the amine group, causing the intermolecular charge transfer of the molecule to be stopped. This, in turn, stops the fluorescence. If we add base to the “ON” state of the molecules, we cleave the lactone bridge. This allows the structure to adopt a non-planar conformation. Since the molecule is non-planar, there is no pi-bonding between the rings. This also stops the fluorescence and leads to the second “OFF” state.

Figure 3



As mentioned, the usefulness of these switches would be increased once the third state is achieved. Two-state molecular switches often find uses in more basic nanotechnology devices, whereas a reversibly switching three-state molecule could have more in-depth nanotechnology uses. These potential applications could include molecular wires, molecular conductance switches, potentiometers, molecular logic devices, and more.

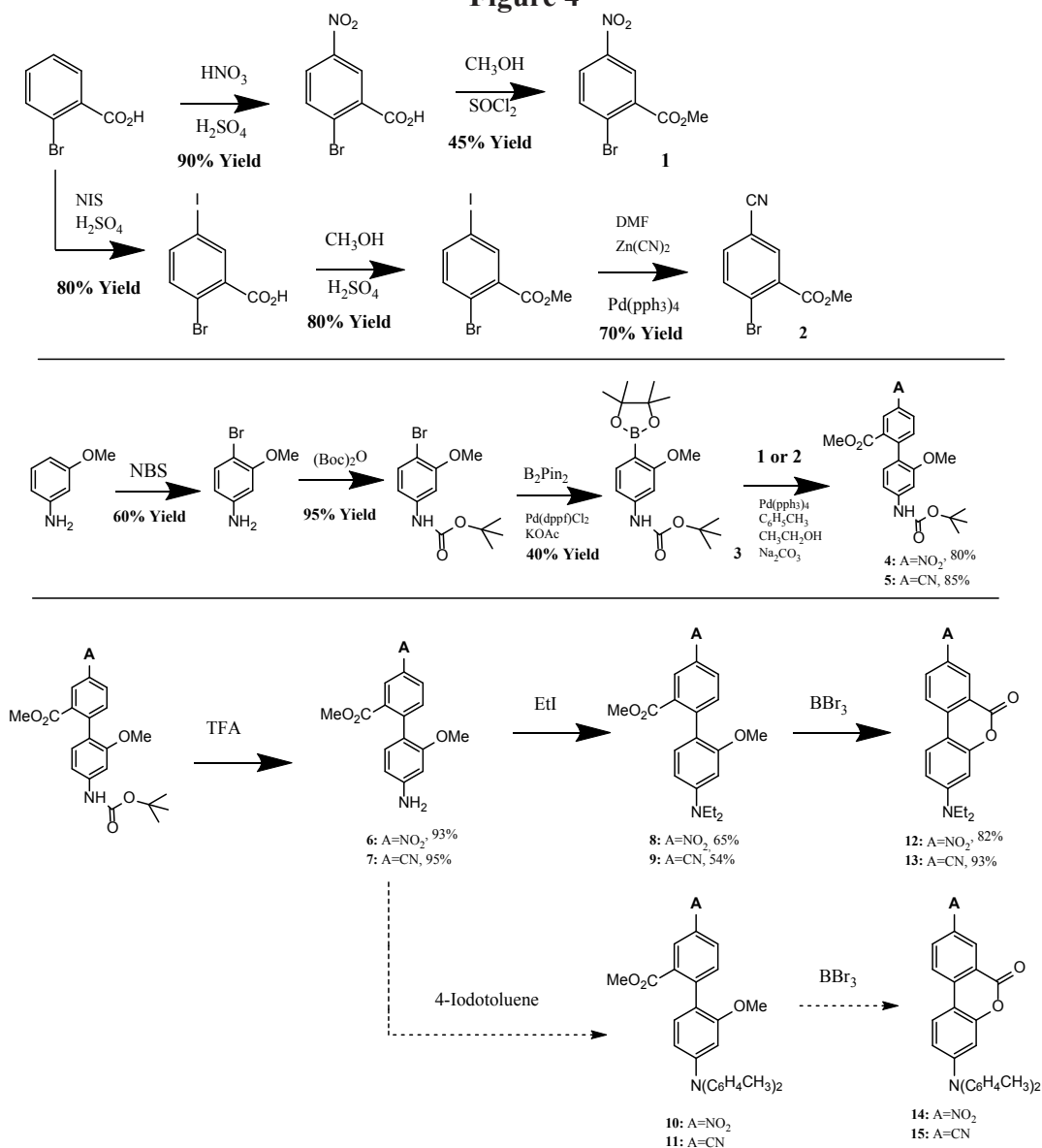
Experimental Synthesis

Overall Synthesis

The synthesis of our molecular switches involves two different reaction paths to synthesize the top and bottom phenyl rings, which later get coupled via a Suzuki reaction. The complete synthesis diagram of our research can be seen in Figure 4. Each arrow represents a separate

reaction, most of which are air sensitive and run overnight. Take note that the reactions with a complete black arrow are those that our group has successfully synthesized, while the dotted arrows are those that we are still working on. The percentage underneath each arrow shows the percent yield of the reaction, which is how much product we obtained versus how much we expected based on starting materials.

Figure 4



Reactions in synthesis work are trial and error, wherein we find a reaction with a similar end product and customize their procedure to suit our reactants. Reactions are often done multiple times with slightly different conditions or completely new procedures. Molecule 3 for example was first attempted via a borylation reaction with the simple amine molecule. This reaction route resulted in protodeboration, where the molecule forms and then immediately decomposes. By adding a protecting group, seen at the bottom end of molecule 3, were able to find a workaround

for this difficulty and successfully couple the top and bottom phenyl rings.

Each reaction has a procedure that indicates how much of each reactant is used and how to set up the reaction. An example of the procedure for molecule 2 on Figure 4 can be found below, along with the characterization information used to identify the compound.

Methyl-2-bromo-5-cyanobenzoate: Methyl-2-bromo-5-iodobenzoate (2.77g, 8.13 mmol) was dissolved in 40 mL of DMF and sparged with Ar for 15 min. $\text{Pd}(\text{pPh}_3)_4$ (0.520 g, 0.450 mmol) and $\text{Zn}(\text{CN})_2$ (1.07 g, 9.15 mmol) were added, and the mixture was heated at 70°C and refluxed under Ar for 16 h. The reaction was cooled to room temperature and then diluted with H_2O . The reaction was extracted 3x with 100 mL of Et_2O . The combined organics were washed 3x with 25 mL of brine, dried with MgSO_4 , filtered, and the solvent was removed under reduced pressure. The crude product was purified with column chromatography (20% EtOAc in hexane) to achieve a white powder (1.52g, 78%). ^1H NMR (400 MHz, CDCl_3) δ 8.1 (d, J = 1.7 Hz, 1H), 7.82 (d, J = 8.3 Hz, 1H), 7.6 (dd, J = 8.2 Hz, J = 1.8 Hz, 1H), 3.98 (s, 3H).

We successfully synthesized two of the four molecular switches thus far as indicated within the synthesis diagram. The nitrile-diethylamine switch and the nitro-diethylamine switch. In total, these molecules required 7-8 separate reactions for completion. The restricting factor on synthesis within our plan is the borylation reaction, resulting in molecule 3. The yield on this reaction ranges from 25% to 40%, which requires significant time to prepare the precursor molecules with high enough quantity to produce this molecule.

Flash Chromatography

After a reaction has been completed or run for an adequate amount of time, collection, and purification of the product of interest is necessary. After completion, we have a solution containing multiple solvent, starting materials, intermediate products, and presumably the intended product. To separate these components, flash column chromatography is conducted. Flash chromatography is a variant of regular column chromatography, which separates molecules based on the polarity of their structure. This alternative utilizes air pressure to separate components rapidly and is very common within organic chemistry.

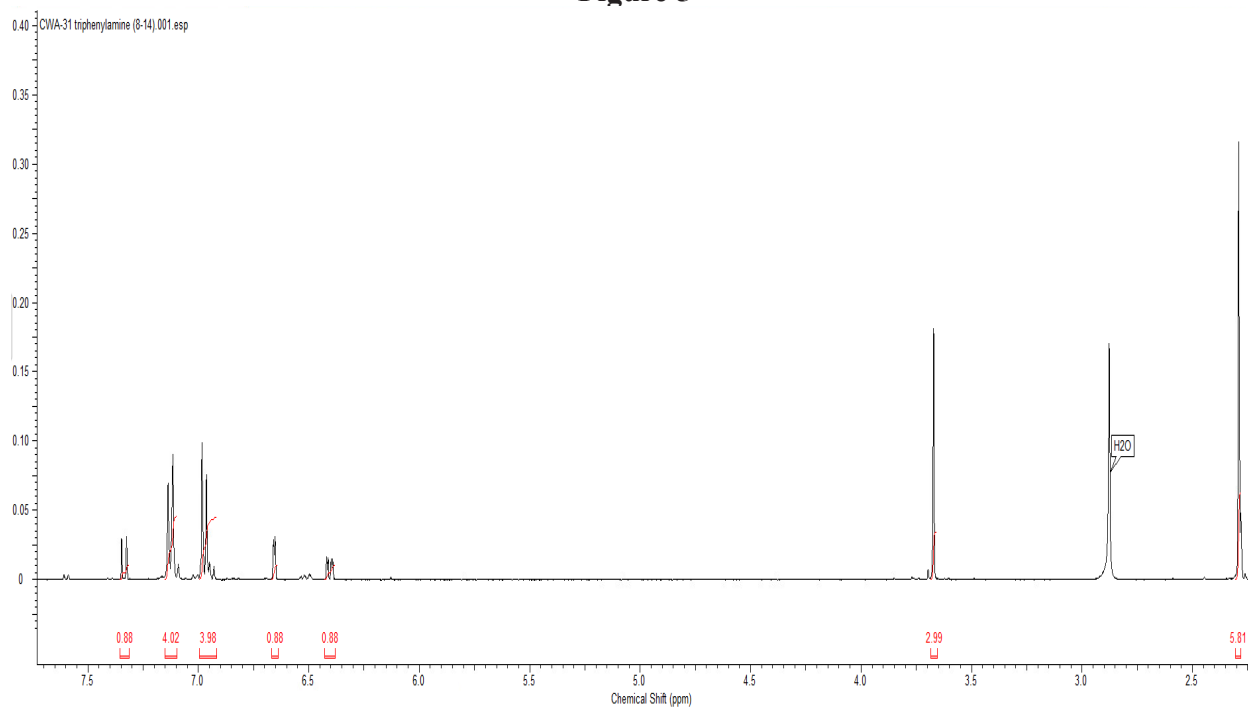
The separation of components is based on the polarity of the molecules. Polarity stems from the bonded atoms sharing electrons unequally. Due to the electronegativity of an atom, it might have a stronger pull on the electrons. This unequal sharing results in partial dipoles throughout a molecule. The overall dipole moment of the molecule will explain the polarity. A flash column contains two components, the moving phase and the stationary phase. Depending on the polarity of the molecule, it will either be more attracted to the moving phase and move quickly through the column, or it will be more attracted to the stationary phase and move slowly through the column.

By examining our theoretical products, we are often able to predict the relative polarity of the molecule and when it should come through the column, allowing for collection and ultimate purification. Excluding very few of the reactions within our synthesis diagram, the majority of the reactions require column separation after completion. This separation not only allows us to collect our intended product, but also any starting materials for repurpose. It is also possible to collect any alternate products collected in order to analyze them and determine what went wrong with the reaction or what could be improved overall.

NMR Spectroscopy

Nuclear magnetic resonance spectroscopy is a widely used tool within chemistry. Although this type of spectroscopy is mainly utilized by organic chemists and biochemists, it is applicable to any molecule that has nuclei with spinning states. NMR observes the spin states of the nuclei in relation to the magnetic field generated. The data given by a NMR is in the form of chemical shifts. To interpret the chemical shift of your subject, there are several different components to consider that would affect the shift on your spectra. Bonding to an electronegative group and hydrogen bonding are aspects of your molecule that could change the location of the signal on your spectra.

Figure 5



NMR spectroscopy is the quickest way for our group to identify a potential product, compare to ensure we have the same product, or determine purity of the product. The specific form of NMR used within this research is proton NMR where we focus on the hydrogens residing mainly on the biphenyl rings. An example of a typical NMR can be seen in Figure 5. Depending on the location of the protons, we expect to see them in certain ranges within the NMR. For example, Figure 5 shows the aromatic region of the NMR at the left of the spectra. This region is named due to the protons found in the region generally being located on an aromatic ring, like the rings found within our molecular switches. One example of a common impurity within a sample can be seen at around 2.7 ppm, which signifies the region where water is found. Samples can collect water through the air, so being able to detect this impurity via NMR is very important.

X-Ray Diffraction

The successful synthesis of the final molecular switches was determined initially via

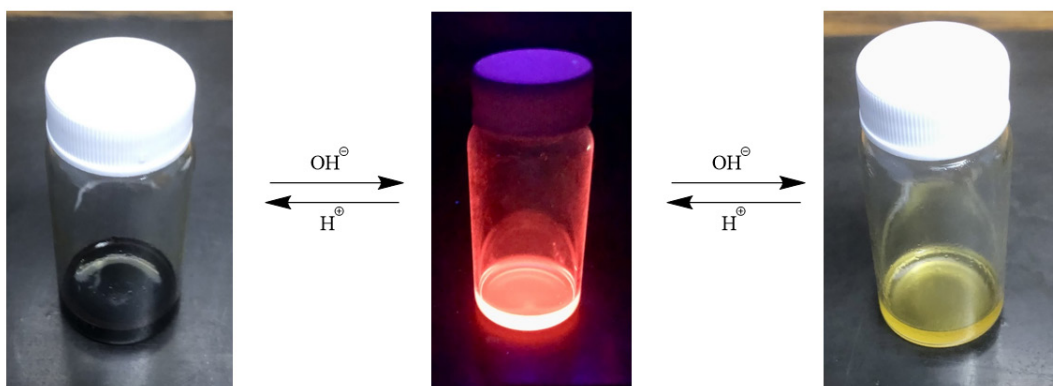
NMR spectroscopy. Due to the importance and ultimate nature of these molecules, further characterization was done in the form of X-ray diffraction. This is a technique used to determine a sample's crystalline structure. Based on chemical concepts, this technique essentially draws your molecule for you. This allows a researcher to confirm the overall structure of their sample. The limiting factor with this analysis is that you must have crystals of the compound you wish to study. After collection and purification of our compounds, the samples are in the form of a powder. Crystallization of the final two compounds needed to be done using different methods. To obtain the crystal of the nitro-diethylamine compound, the compound was dissolved in dichloromethane and allowed to slowly evaporate into the air at room temperature. This easy process afforded large red crystals, which were given to a fellow professor at our college to identify.

The process to obtain crystals for the nitrile-diethylamine compound was more rigorous. Slow evaporation of this compound resulted in a film rather than crystals, which does not work for X-ray diffraction. Instead, the technique of vapor diffusion was used. For this process, a small amount of compound was placed in a small vial which was combined with a solvent it could dissolve in. This smaller vial is put within a larger vial containing solvent that the product is insoluble in. The combined vials were then put in a cold environment where the outer solvent was allowed to evaporate and enter the smaller vial. Since the molecule is insoluble with the outer solvent, it is very slowly forced out of the solution. This ultimately results in crystals forming on the inside of the smaller vial. The yellow/orange crystals obtained were still difficult to analyze and had to be sent out of state for analysis.

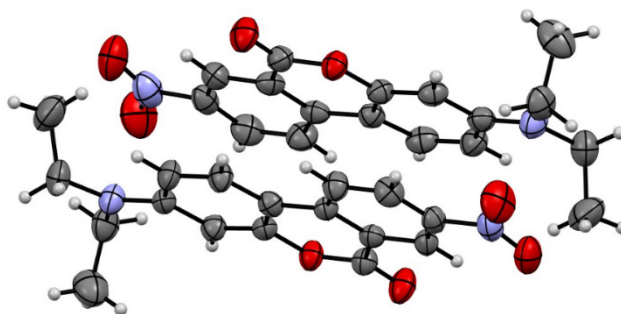
Results and Discussion

Nitro-Diethylamine Switch

The first switch obtained during this research was the nitro-diethylamine switch, which was promptly tested for the switching capabilities. This compound can be seen in Figure 4, molecule 12. Initial tests for pH driven conformational change were done on a small scale in the laboratory. This compound is red as a powder and it orange once dissolved in a solvent such as dichloromethane. Under a UV lamp, the solution fluoresces a bright orange color. The switching of this molecule can be seen in Figure 6. This diagram has the same overall format as Figure 3 in the molecule having the amine group protonated, unprotonated, and lactone bridge cleaved. The OH^- above the arrows designates a base being added to the solution and the H^+ shows acid being added. The arrows going opposite directions in the diagram also shows the reversibility of the switching.

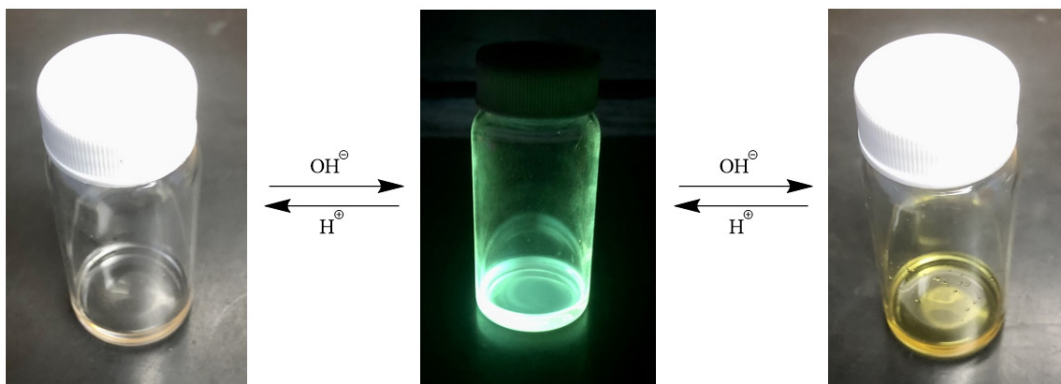
Figure 6

X-ray diffraction of this molecule, as mentioned above, was done with the help of another professor, Dr. Gerlach from UWEC, and can be seen in Figure 7. The first thing obtained from this image was the basic structure of the molecule, to see if we had what we thought we had based on NMR analysis. The optical properties of this compound rely on the planarity of the molecule and this X-ray image confirmed the molecule was very planar. We also learned that there are two unique molecules in the unit cell of this crystal. This relates to how the distinct molecules form with each other in the crystal.

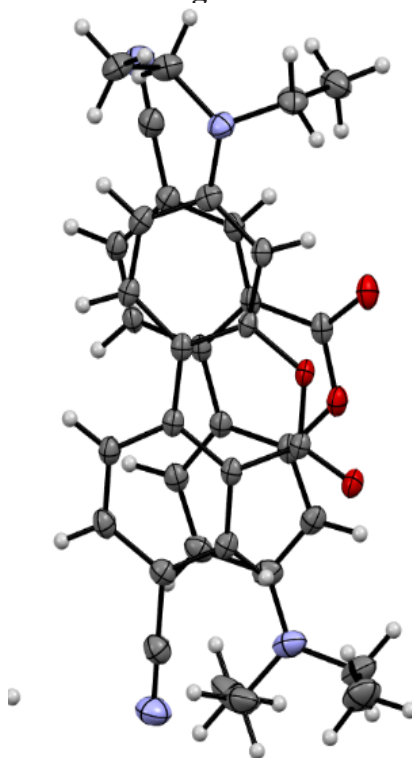
Figure 7

Nitrile-Diethylamine Switch

The second switch obtained in this research was the nitrile-diethylamine switch. This compound can be seen in Figure 4, molecule 12. Like the nitro switch, this compound was also tested on a small scale for its switching capabilities. This switching can be seen in Figure 8. As expected, this compound was visibly brighter than the nitro due to the quenching capabilities of the nitro group.

Figure 8

The X-ray image was also able to give some information about the difficulty behind crystallization and X-ray analysis. The crystals for this molecule are merohedrally twinned. In general, when a crystal is twinned, its diffraction pattern is altered. This complicates the structure determination, hence the reason the crystal was sent out of state for analysis. The planarity of the image was also measured to be around 178° . A perfectly planar molecule would have a dihedral angle of 180° , so this molecule is very planar like the nitro switch. This crystal differed from the nitro switch in that the unit cell contains three unique molecules.

Figure 9

Newly Synthesized Precursor Molecules

Throughout our synthesis, we utilized many known compounds. The unnumbered compounds

in Figure 4 are the known compounds used in our synthesis plan. These previously known compounds were easier to synthesize and identify due to chemical literature available. In addition to the replication of known compounds, our group also had to create completely new compounds that have never been synthesized in the past. The completely new compounds are those that are numbered within Figure 4. Including the two final switches, we were able to create a total of nine new compounds. All nine of these compounds must be purified further and characterized by proton NMR, carbon NMR, melting point tests, IR spectra, and mass spectra in order to publish our results.

Other Two Molecular Switches

The remaining switches yet to be completed, the nitro-diphenylamine and nitrile-diphenylamine, have been postponed due to time constraints and difficulties with synthesis. A recent experiment indicated that molecule 11 was successfully synthesized, in an unknown amount but lost during the flash column. Our group theorized that our compounds have a very low sensitivity on the detector. Therefore, instead of collecting the product the machine dumped them into the waste container. The Dahl research group may continue the attempts to synthesize these remaining switches in the future.

Conclusion

We have conducted experimental organic synthesis to produce several new three-state “OFF”-“ON”-“OFF” molecular switches containing an acceptor group, donor group, and lactone bridge situated on a biphenyl skeleton. Two of the ultimate switches were successfully synthesized and shown to have switching capabilities. The newly synthesized seven precursor molecules, along with the two final switches will be further categorized with UV-vis, fluorescence spectroscopy, melting points, carbon NMR analysis, melting points, and mass spectroscopy. The success of this research provides a deeper understanding of the range of molecular switches as well as the future work possible with the biphenyl structure.

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“Whether or not you reach your goals in life depends entirely on how well you prepare for them and how bad you want them.”

Ronald E. McNair