ILSURJ

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ILLINOIS

THIS ISSUE

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It is with great pleasure and excitement that we introduce to you the inaugural issue of the Illinois Undergraduate Research Journal (ILSURJ). As the Editors-in-Chief, we are honored to present this platform, which embodies the culmination of tireless dedication, passion, and collaborative effort from our team and contributors.

The inception of ILSURJ stemmed from a deep-rooted belief that the University of Illinois Urbana-Champaign deserves a dedicated multidisciplinary publication for undergraduate research. As a globally esteemed research institution of the highest caliber, Illinois fosters an environment where undergraduate students engage in remarkable scholarly endeavors across various disciplines. However, the pathway for these aspiring researchers to disseminate their work in esteemed journals can often be challenging. ILSURJ emerges as a beacon to illuminate the outstanding research achievements of our undergraduates, providing them with a platform to share their insights, discoveries, and innovative ideas with the world.

Since its conceptualization in October 2022, the journey to bring ILSURJ to fruition has been nothing short of exhilarating. Countless hours of brainstorming, meticulous planning, and unwavering dedication have been invested by our team members to ensure that this journal serves as a testament to the exceptional quality of research conducted by our undergraduate community.

We extend our heartfelt gratitude to every individual who has contributed to this endeavor - from our diligent editorial board and dedicated reviewers to the brilliant authors who entrusted us with their manuscripts. Your commitment and enthusiasm have been instrumental in shaping the identity and vision of ILSURJ. We would also like to especially thank the Illinois Office of Undergraduate Research, the Illinois Library (Assoc. Prof. Merinda Hensley in particular), and our faculty editorial board for their immense support throughout this journey.

In this inaugural issue, we present a diverse array of research topics that showcase the breadth and depth of scholarship at Illinois. From exploring the intersection of technology and society to investigating the complexities of human behavior and cognition, each article encapsulates the essence of curiosity, exploration, and academic rigor that defines our university. Such an opportunity to publish research across disciplines exists only with ILSURJ, providing a unique platform for undergraduates to showcase their scholarly contributions and engage in interdisciplinary dialogue.

As we embark on this journey, our mission remains steadfast - to bridge the gap between undergraduate and graduate research, foster interdisciplinary collaboration, and inspire a culture of inquiry and curiosity within our community and beyond. May this journal serve as a catalyst for intellectual discourse, innovation, and transformative ideas that shape the future of undergraduate academics at Illinois.

Thank you for joining us on this momentous occasion.

Warm regards,

Varshal Patel & Dipankar Yettapu
Editors-in-Chief
The Illinois Student Undergraduate Research Journal (ILSURJ)

ILSURJ

INTERVIEWS

A True Teaching Professor: Dr. Ali Ansari

Trisha Haria

Dr. Ali Ansari has vast experience teaching and learning across a variety of different fields — including electrical engineering, cancer research, and microfluidics. Currently, Dr. Ansari's main focuses are bioengineering and teaching, as a teaching professor in Illinois's Bioengineering Department. He is a big believer in improving accessibility to learning especially difficult concepts by making fun of them or by gamifying them. He also loves to see students' eyes light up when they finally understand a difficult concept.

INTERVIEW 1

What is your teaching philosophy?

My philosophy is to make education accessible by making it less scary. One of the things that I do research related to teaching is trying to sort of make fun of different concepts that are typically viewed as scary. Science should be open to anybody who can and wants to learn it. I think the “can learn” part is the part that we change, right? We can make science so it's silly; we can make science so it's fun. I think that's what I want to be able to do with teaching; people should be able to play with science and I think that should be more of what we do.

Describe your educational journey.

I started off as an undergrad in electrical engineering and I focused on a lot of the elements that are bioengineering-adjacent in terms of electrical engineering.

The Periodic Table of Elements
Visualized through electrons
By Alison Haigh

I decided to do a masters, so I came to the University of Illinois and then I started working in a lab. I joined the lab for about a semester, and then the professor who hired me asked me if I wanted to do a Ph.D., and I said sure. After that, I decided to do my postdoctoral at Case Western Reserve University and there I worked at three different labs because I found that I find a lot of things really fascinating.

A lot of my specialty is in microfluidics, but when I was in my postdoc, most people didn't do that kind of research. I wanted to learn how to do a lot of things, so I began to study how to do drug delivery, which is how you get one drug that you put into the body to a certain location over a certain time for a certain amount of time.

I also learned how to do polymer chemistry, which is how to make things attach to each other and react in a certain way. I studied bacteria, then I also did a lot of work with cancer. In one study, we had a doctor who was operating on mice brains. I did this for my first position, but my second position was much more focused on the heart, so I did a lot of cardiovascular research on regeneration of heart tissue.

I found that throughout that entire time, the constant thread was that I would always get in trouble for teaching people. Solving a puzzle? A lot of fun. Watching or teaching somebody else how to solve a puzzle was like an order of magnitude more fun. So I decided that instead of going the academic route, I went through the teaching route, and I went on to become a teaching professor.

I'M NOT A RESEARCH PROFESSOR, I'M A TEACHING PROFESSOR.

I'm not a research professor, I'm a teaching professor. We focus on how to better teach and how to improve ourselves so that we are able to teach people more effectively.

How did you arrive at bioengineering and teaching as your two current focuses in your career?

My dad is a pathologist, so throughout my entire life, science was just like a way of defining what the world was in a way that wasn't scary. I would just be like "Why does this work?" or "How does this work?" and my dad would just tell me. Knowledge was just something that was not meant to make people feel small or ignorant or anything like that; it was just sort of a way of defining the world.

For me that's what bioengineering is: a way of defining the body in a way that makes sense. I mean, if you think about it, it's a machine, right? The brain takes a signal and does something to it - it's all connected in a way that's able to be understood, and I think that's what bioengineering does. It gives us the language of organizing that information. Why did I choose teaching? That's a little harder. I think that was more of a personal thing that I found was more rewarding.

Now, why do I teach bioengineering? I think we live in the center of so many different fields. We are the melting pot of everything that matters. I feel material science touching the body is

us. Electrical engineering touching the body, that's us. Mechanical engineering touching the body, that's us. Chemistry, biology, physics touching the body, that's us. We are, every single finger we have is in a different place that connects all back to us. I think that that is the most beautiful thing.

A lot of the problems that we have, other fields have done in a different way, and so we can gain so much knowledge by drawing inspiration from translating these problems from different fields. That is such a powerful thing. Learning about different diseases, different kinds of cures, different kinds of treatments constantly pushes us and requires us to sort of be on top of it, right? We can't become irrelevant. Biology moves fast and that feels really good.

What is your research related to?

I currently research making games or really turning lessons into some sort of gamified or game-based learning activity.

I have a paper that I just submitted this year, basically talking about how making games is actually really hard, because depending on who your student population is, the games can also be not inclusive. I made games that were all word games, because I love word games. They worked in some departments well, but when I tried to do them in various departments, where the two demographics were different, the word puzzles for them were tedious.

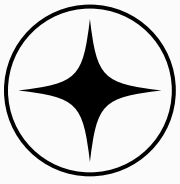
In one scenario, it happened to be that many of the students' native languages were not the same as the language the games were in and the language they had to play in. In fact, many of them asked me if the word puzzles are even required, and I realized that these are a hassle to the students because they're not playing in their native language. They're not doing this because it's fun, they're doing it because they have to, so I tried to build games that were more Matlab or math based.

What have you learned so far while collecting information about your research, from papers and other sources?

There are a lot of ways to fix things, but there's a lot fewer ways to assess them, meaning knowing if what you're doing is helping or not is actually a very difficult thing to do. Figuring out how to assess that is actually entirely people's fields of research. One thing that I've gleaned from reading papers in my field is that there's a lot of things that we try to improve upon and we try to get better about, but we don't always know if it's in the right direction.

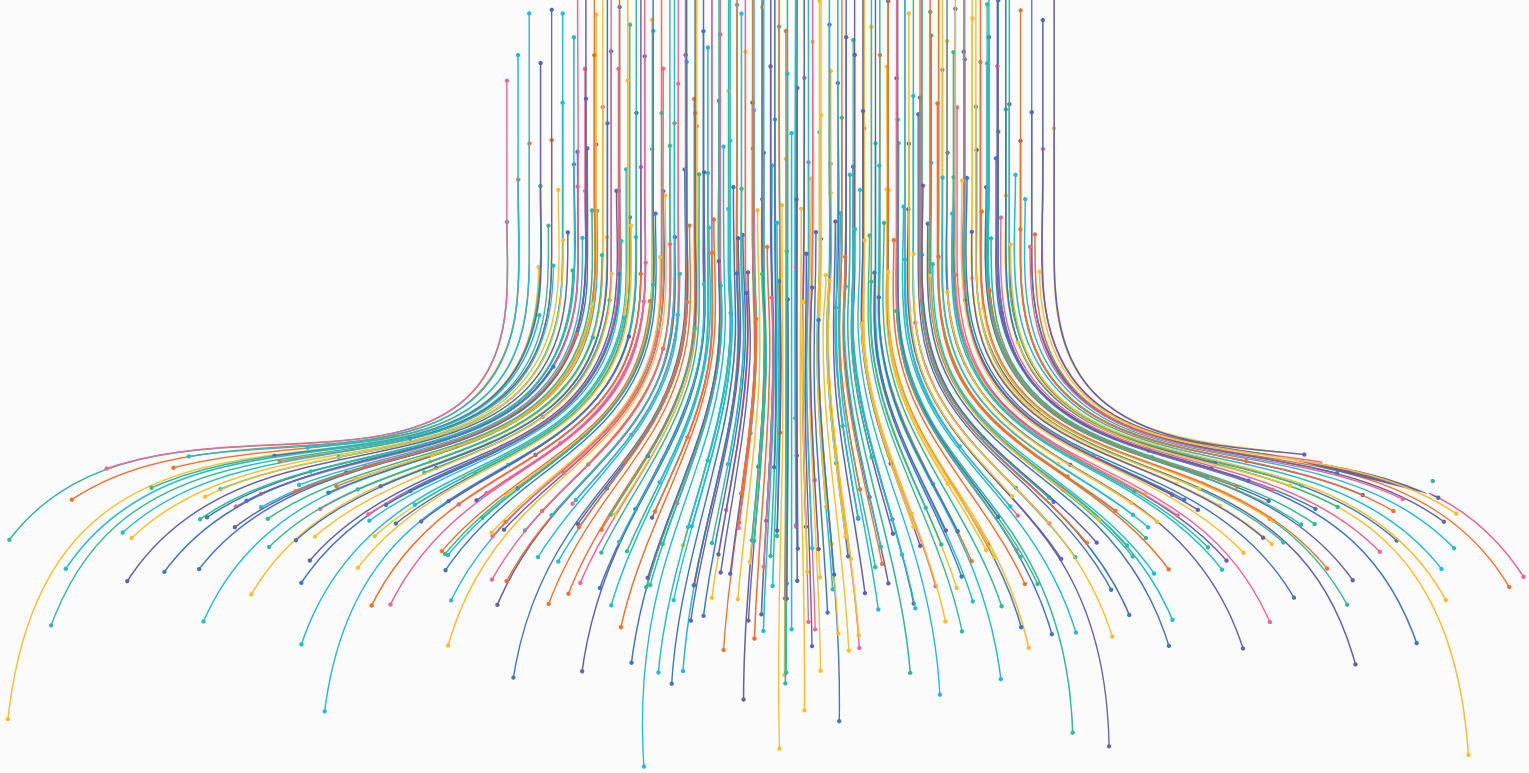
What advice would you give undergrads who are interested in bioengineering?

The most important thing that I could tell them is to try to do things that you don't think you'll get to. Try to learn things that you don't think you'll be able to succeed in. I think taking a chance and putting yourself into a situation where you have to commit is good for you because it'll show you how well you can do things that you don't think you can. Try things. I think undergrad is an opportunity for you to take chances and learn things.



TRY TO LEARN THINGS THAT YOU DON'T THINK YOU'LL BE ABLE TO SUCCEED IN.

-- DR. ALI ANSARI



The process of a new lab: Dr. Min Jee Jang's BioE lab focusing on neural engineering

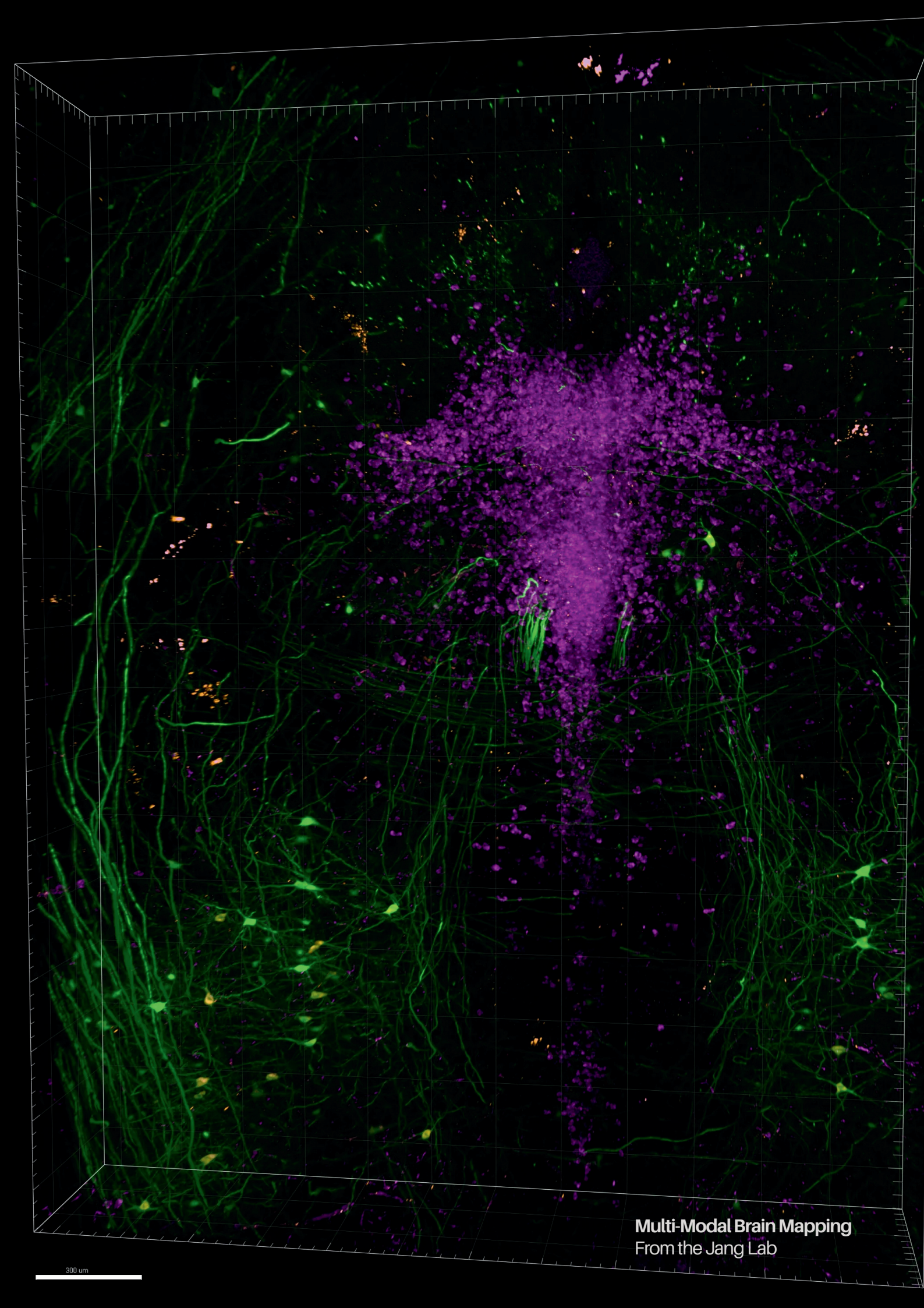
Kelly Shin

Dr. Min Jee Jang is a tenure-track professor in the department of bioengineering at the University of Illinois Urbana-Champaign. After developing her extensive undergraduate research and engineering background at renowned universities KAIST and Korea University, she worked as a postdoctoral scholar at Caltech using techniques such as viral vector engineering, special transcriptomics method, and gene therapies. When she can, she spends time with her best friend---her five-year-old son---and enjoys drinking coffee and eating ice cream.

INTERVIEW 2

What did you focus your research on in your undergraduate and graduate years?

I started as a research assistant as a junior, and at the time I was studying how neurons can grow on a nanoparticle or nanopattern surface, because the whole idea of the research theme that I was interested in was how we can build simple brain circuits in a dish. Because the brain is so complex, you can really dig into what kind of parts are re-



Multi-Modal Brain Mapping
From the Jang Lab

ally important and how they interact with each other. The idea at the time was that if we can build a very simple brain circuit with live neurons, then we might be able to tackle those questions in vitro.

In light of that work, I was involved in a research called brain-on-a-chip, which is where we make a simplified version of brain circuits on a chip, so that we can record it or simulate the neurons individually while we have a defined circuit architecture. What we had done was make a pattern of a surface, because neurons like to explore the chemical or physical surface when they grow on a dish, so we tried to tweak those patterns to see if we can control neuronic growth in a dish.

I switched fields to more in-vivo, like with animals, when I joined Caltech. The first thing that I did in my time at Caltech was that I was involved in a project using tissue clearing, which is a technique where you can make a large chunk of the tissue transparent, so that you can easily see through the biomolecules inside of the tissue. The lab had started engineering viral vectors for making gene delivery more efficient to the brain, because previously we had to inject the viruses into the brain directly to express the genes we wanted to deliver. That was my start in getting involved in AV or viral vector engineering. Since then I was involved in a lot of viral vector engineering, which has made AVs able to deliver genes to the brain through the bloodstream like blood vessels, so we can just do IV injection to deliver genes to the brain.

My latest work was developing a special transcriptomics method to profile the AV transduction in different cell types in the brain, so that we can know that the AVs that we inject will go into different cell types into the brain.

How has your journey been in researching and eventually teaching in America? Did you face any challenges along your journey?

Oh, a lot. So, all my educational time has been spent in Korea, and I moved to the States around 7 years ago and everything was different. Culture differences. Doing research in the States is great and I chose this job to keep going, but being an immigrant was much harder than I thought, especially with the language problem. I spent my whole entire life in Korea, and when I moved here it was very hard. I can't imagine how I will teach students, actually. The language was a big hurdle. A lot of the time visas were another issue for me to continue my research.

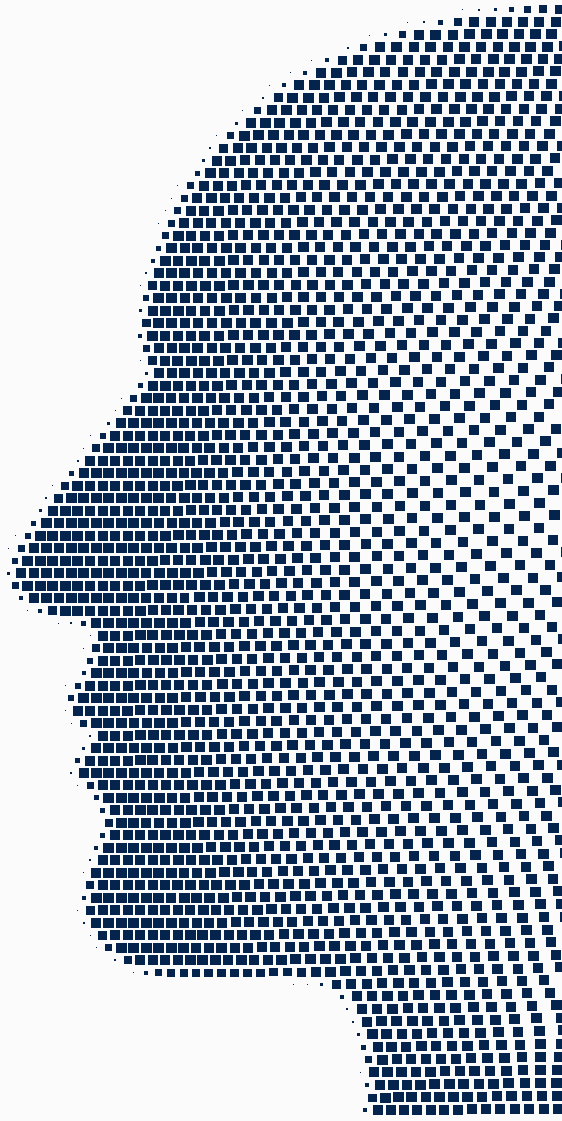
Why did you choose to accept the tenure-track position when you were doing research beforehand?

The tenure-track professorship doesn't necessarily focus on teaching. It's different from teaching faculty. There are specialized professorships as well. I believe we have a tenure-track for specialized professorship as well, but I am in a regular professorship. In my duty, the majority of the time I will be doing research, and teaching is also a part of it, but the main reason that I chose this job was just because I found a very big opportunity to do research at least in my field. And I guess for me the most important part was how good the area would be to raise my kid.

Your lab was scheduled to open for January 2024, making it one of the newest labs at Illinois. Could you shed some light on what the process is like? From deciding your research areas of interest, finding undergraduates and graduates as a PI, et cetera.

That was a really big question I had, yeah. So, deciding your area of interest is something you have to do for your job application. I had been thinking of my research areas of interest when I was in postdoc and applying for a job in academia, and it's still developing and not really fixed. When I started here I was really fortunate to have a great lab space and generous support from the department.

The first thing that I did was buy a lot of equipment to fill up my lab space. Because I started in January I couldn't get graduate students. So I found some undergraduates to get some help. Luckily my colleagues were very kind and would forward students to me that might be interested in joining the new lab. I was able to recruit some great undergrads, and I am trying to hire some graduate students this cycle so that we can work with them this fall. I have a few that I am communicating with.



With setting up the lab was it based on the research that you did previously, or did you decide what to get based off of the research that you know you are going to do?

Of course it should be relevant to your future research, but the future research is highly relevant to my previous work. I have my knowledge and expertise there that I can expand into my future research. So the equipment that I bought was of course relevant to what I am going to do, but it was also equipment that I had used before too.

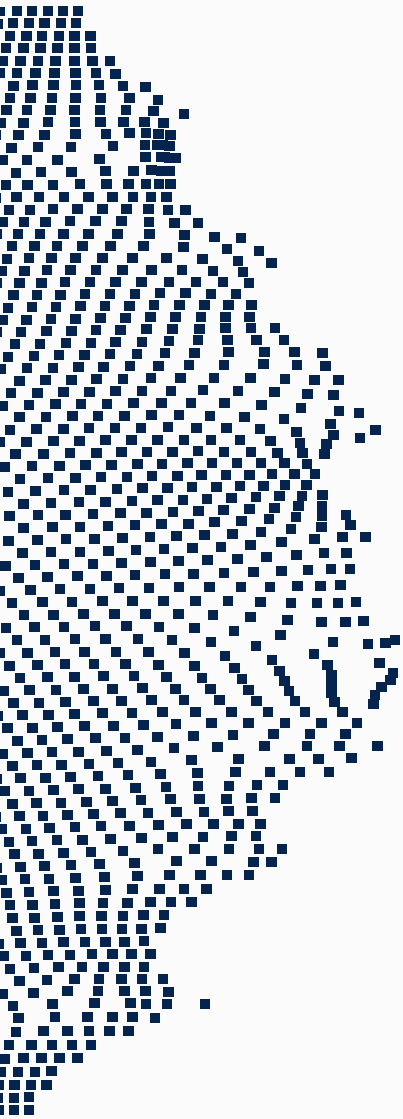
Anything interesting that came up from setting up the lab?

It was harder than I thought, and it's been slower than I thought. It may be particular to me, but for me it is really hard to decide it all. I have maximum freedom. You must decide what you want to get and where to put the items. There are a lot of things that I had not experienced before becoming a PI, so there are a lot of minor things that I had to struggle with, I should say. I have been receiving a lot of help from the department and other relevant offices on campus so I think it has mostly been resolved. There are a lot of things that I have to do in the future, but I feel like I am on track to get there at some point.

The interesting part was that there are many parts that I hadn't thought of before. For example the regulations and protocols had to be approved before we started our research.

My previous lab as a postdoc was very big and there were people that managed the lab and its miscellaneous items, so I didn't have a chance to get involved with those things. Those were aspects that were behind the scenes that were very challenging, and I feel like are still challenging.

It's a really big thing and building a lab is something I've never done before so there have been many challenges. But it is also very interesting, how the lab is being set up in the university.



Is there a certain approach you take when conducting your research?

So my background is strongly engineering. I am interested in solving technical problems. So if someone brings up technical problems, I want to solve it.

What I really like about the field that I am working on, which is gene therapies, is that I can actually help patients, hopefully in the near future. That was something that I was very eager to pursue.

Because I am an engineer I try to solve technical problems that scientists have. For example if one scientist wants to solve this problem but doesn't have a good technique to tackle that, that could be my start and I would work to resolve that technical limitation.

What motivates the research you plan to pursue in the Jang lab?

For me I kind of switched my field from PhD to postdoc. My PhD was all about in-vitro studies, and I switched into gene therapy, vector engineering, and special transcriptomics - which is totally different from what I was doing with my PhD. One of the reasons that I try to keep pursuing my postdoc research is because I didn't want to develop something just for science. I wanted to develop some technique or technology that could help people, so that was a big motivation for me to switch my field towards gene therapy.

For my PhD we started brain-on-a-chip tech to answer questions about very basic neuroscience. It will be very useful, but how we can actually translate that into therapeutics for example will not be very intuitive. On the other hand, gene therapies have a lot of potential that can be applied to therapeutics - and it's even already been done in a commercialized product. That is something that I hope to pursue at a later point and that was my thought when I switched my focus towards the field.

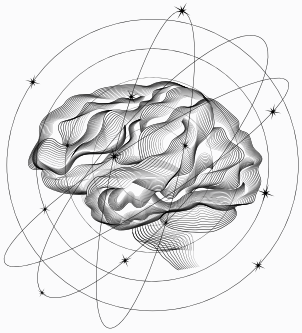
What kind of qualities or skills do you look for in prospective undergraduate researchers? Any advice? What were you looking for specifically?

I think this is particular to me, but I have always looked for someone who is interested, proactive, and very persistent. I don't think undergrads necessarily need specific skills to be a part of this project, but right now I just wanted to engage with students who had been really enthusiastic, like getting involved with this lab. Sometimes even for me I had nothing to do, and I couldn't imagine an undergraduate would be very happy with being involved in this kind of lab. My undergrads are literally unpacking things and trying to organize materials, and I warned them that for this semester this was going to be something they'd have to do. We cannot do any research or experiments before we get our protocol and safety procedures approved. And even so, my undergraduates were very willing to join the lab and help me out, which I'm really grateful for.

Research is not about just doing experiments, there are a lot of behind the scenes that need hands-on work. And my undergrads are generously helping with that. They are very enthusiastic to learn as well. A lot of things we do right now are journal club things and reading research articles together, and my undergrads try to find joy out of it. What I am looking for in an undergrad who wants to join my lab is a willingness to do those kinds of things and enthusiasm.

What are your personal and research goals moving forward?

My personal goal is being a good Mom. I believe there are a lot of ways to parent, but for me, I want to be like his best friend for life. My parenting goal is to make him an independent person, watch him grow, and be his good friend. For research I would like to develop a new, innovative method to cure incurable diseases. I'm also really interested in psychiatric diseases. I am hoping that, while I am in my beginning phase, I am on track towards that goal.



I WANTED TO DEVELOP SOME TECHNIQUE OR TECHNOLOGY THAT COULD HELP PEOPLE, SO THAT WAS A BIG MOTIVATION FOR ME TO SWITCH MY FIELD TOWARDS GENE THERAPY.

-- DR. MIN JEE JANG

INTERVIEW 3

Insight into TJ Byun's Journey: Uniting Music, Business, and Life Acumen

Kelly Shin

TJ Byun is a senior at the University of Illinois Urbana-Champaign, studying economics with a minor in business and is on track to graduate in December 2024. In his free time, he likes to listen to and make music, play basketball, and read nonfiction books about finance, behavioral economics, and venture capital. Previously on the pre-med track, TJ has switched into the music and business route and is currently pursuing many interests, including law. As the co-founder of Lunar Media and one-half of music duo SeoulFly, TJ provides unique insight into his journey exploring opportunities, life, and building business intelligence.

Did you have any prior knowledge of music before pursuing it?

When I was in pre-K to first grade, I was in piano classes where I learned general chords and how to read sheet music. That really helped me, especially with harmonizing. That's one of my favorite things I do in songs, where I try to come up with different harmonies for whatever main melody I have.

I give credit heavily to piano and also being in a choir that had very few boys; I had to learn to mix my voice with very high range voices. Being in choir and band helps you balance and mix your voice with other people. I wouldn't say I consider myself classically trained in any sense, but I was exposed to certain things in certain periods of my life that did I guess put me at an advantage over someone who never really was exposed to it.

What roles do you play in relation to making music? Are you a songwriter? A producer? Or do you see yourself as something else?

The way that Jonathan Lee, my duo partner, and I go about our music has very much evolved with each period of music that we had. In the beginning in 2019, we were very hands on about how the entire song went. Our producer and friend Adam Chung, who was a computer science plus music major at Illinois, asked what to do so I was directing on a small scale.

Recently, I've had more specific ideas about what I want songs to sound like; for example, right now, I really want a cowbell in a song. I help out with the general direction of songs sometimes, but our producer is really talented; he's one of my close friends and I trust him. I don't need to give him any advice at all just because he usually knows what I want and he makes the music sound great.

Other than that, everything that you've heard me sing on our songs was written by me: melodies, harmonies, lyrics, everything. I don't really have a hand in the mixing and mastering process, but I have a very high level of respect for those people because it's so incredibly hard. I tried, and I have a couple of demos where I mixed them myself, but those will never see the light of day.

For me, my favorite part is at the end, when your producer sends you that final mix and master, and it's exactly how you wanted it to sound like. In terms of what I like about the process, it's not my strongest point, but I really enjoy writing lyrics. I can basically say anything I want and share any message I can think of in the form of a 2-3 minute song and it could potentially reach billions of people. I could change so many lives with basically a 3 minute song.

How do you approach your songwriting process? What is the research like for getting into music?

First, I create something called "reference playlists," which are playlists of songs that I think go together to make one sound, or are playlists of songs that I'd like to make a song of each different kind. Usually, they're playlists of different ideas of sounds that I want to put together into one song. This usually goes into a distinct genre from this playlist that I want to make.

From there, I usually just Google the genre and songs. Then, I go onto Genius and see if it's something I can actually do justice with my personal experience, or if I can create a story with the type of music. I usually then request a beat or I go to YouTube and look for type beats. If I use a type beat, then I go to my producer to remake the beat or change the song completely. From there, we do revisions, change lyrics, and add or remove things to make the songs more interesting.

How has it been connecting with other artists and musicians?

It's been amazing! We have added a lot of people in our network. Both of us are social people, and we love networking; we meet new people practically every day. We've worked with Irene Wong, Aleebi, and we've been able to get to know them. have them be in our songs, and get advice. I would even say every industry is very connection-based. That's how I got involved with being able to open for JUNNY, Shaun, brb., all those guys.

I noticed you had a lot of interests. How did you get into venture capital and Lunar Media after pursuing SeoulFly?

I was always around music. I watched "Never Say Never" by Justin Bieber, and I say this because it is monumental in my life. I thought wait a minute, that's really cool, to be able to make my own music and be like Justin Bieber where I could also play it live. I was really young - that stuck with me for a while.

I was also in a band in middle school and my dad was in a rock band which toured the Midwest for a bit. I always wanted to do music, but it was more of a dream. Then, in 2014-2016 when I was in middle school, I started watching different people on YouTube who made music in just their rooms. I thought this was cool and I went to my friend and said we should try to figure it out. That was when I threw my first sort of "song" down. Funny enough, there was a decent amount of people at my school that liked it. That's when I reached out to my friend Jonathan, who was at my church, and we made a second song about our friend which had about 7,000 streams, which was huge to us at the time. We started to take music more seriously and write actual songs, then released our first duo single in 2019 - which did really well and had about 70,000 streams in three months. That's when SeoulFly was born.

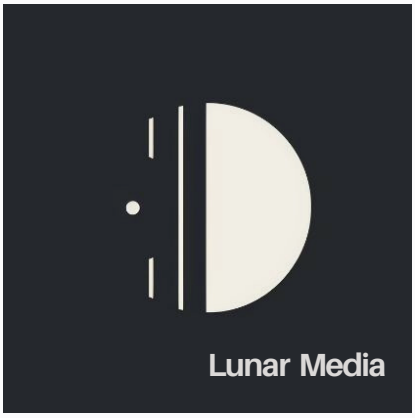
This segues into venture capital and the creator economy space. Jonathan is a year older than me and goes to Stanford, and freshman year he was doing economics and was interested in tech, investing, startups, and entrepreneurship as well. He did an internship at a firm called XRC Labs, and was there for about a year when they asked him for a referral. They regard referrals very heavily over there, and he referred me. Didn't really know much about VC, but after my time at XRC, I thought the VC space was sick. I love the idea that you're at the forefront of next-gen technology. Your decision on whether or not to invest in this company is literally going to change the world. To me, I really prioritize impact over materialistic things, which is why I was really drawn to it. Not only is the VC space full of a lot of bright people, really interesting people, but I found it to be very value driven and I found that really cool.

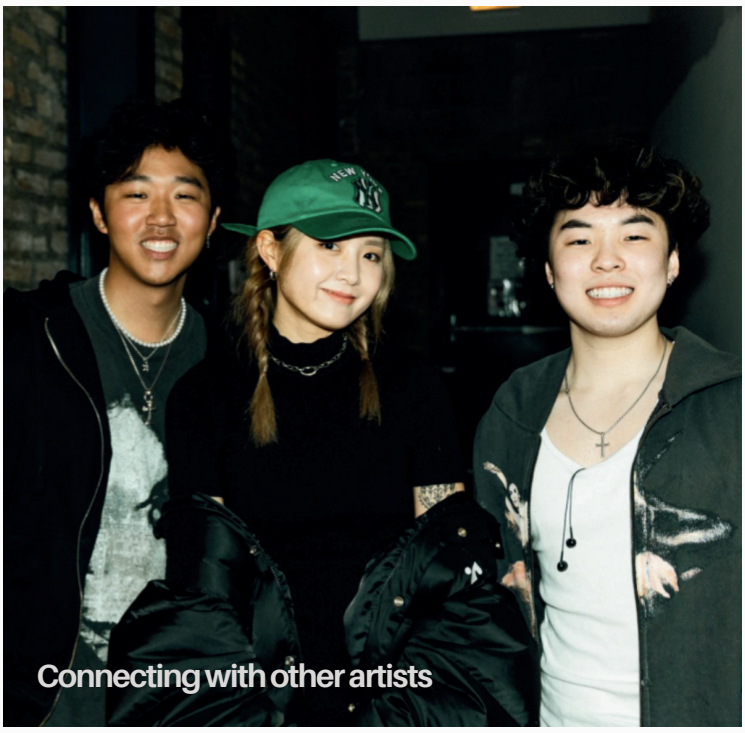
How did you go about Lunar Media after VC?

There's a large gap between my experience at XRC versus Lunar Media. Jonathan began working at a creator economy agency after XRC, and they had a decent sized book of creators - around 30-50. After XRC, I've seen it at one end where people made decisions on investing in startups; I wanted to see what it is to be at a successful high growth startup that had potential to be invested in, just so I can get a fully immersive experience of the startup ecosystem. That's when I joined this creator agency where I worked on campaign management, creator sourcing, finding and assigning new talent, as well as helping on a music marketing strategy campaign and really got my hands wet in creator management and the overall social media marketing space. I helped Jonathan, as well as the co-founder of the past company, start a Latin American branch of the company. That's where I learned a lot about scaling a business and going from A to B.

This leads us into after my time at that creator agency of bouncing around. The first one that I worked with was Melo Music, which is a social media platform for artists to share their music without needing to make content. The premise of it was SoundCloud meets TikTok, where they have the discovery algorithm of TikTok, but the vibes of SoundCloud used purely for music discovery rather than content creation. It was really interesting to see how different that business model was. I helped there in terms of marketing and growth and bringing in new models.

I knew I always wanted to be a founder or start my own thing, but I felt now was the time. Mike is the CEO, co-founder of Simplify, which is an AR job resume platform that makes it easier for students to apply to internships and full time jobs by creating a resume and autofilling for many jobs. Along with Jonathan, we came together with the idea of Lunar Media, and around October or November we started working hard on growing Lunar Media.





Connecting with other artists

A Chicago Show
SeoulFly Music

How far along is the company now?

With Lunar Media we originally started with a roster size of three, people that we knew had a following. Then we began ramping up on making our operations perfect. In the creator space, the biggest cash play is to have as many creators as you can, and a lot of people go for volume and take fees to maximize profit. But for us we care more about doing it right, our whole idea at Lunar is we want to empower Asian creators. We want to make it easier for them to receive deals, we want those deals to be better, and we want them to overall have an easier time receiving a deal, executing it, and getting paid. That's why we are so operations focused and we want to make sure that everything we do has a purpose with no dead steps. In terms of progress since the beginning, we have grown our roster to around 15 since October, with 4 in an exclusive contract.

Are these 'talents' people around our community?

A lot of these talents are social media "stars" who we brought in through email outreach. Myself or one of our interns find creators on TikTok, and if we find a creator that is a fit for our brand, and has the minimum requirements we are looking for, we add them to a sheet and we reach out via email to work with them. We also started to implement a referral system. Mainly in the US, one in Australia, two in Japan, one in the UK - all over.

How are you balancing it all? Pursuing venture capital, Lunar Media, and music with SeoulFly?

I think about this all the time. Realistically, it's very hard to balance. If you ask me how I am balancing it, sometimes I am not balancing it at all. When things are really hard at Lunar, I sometimes spend zero seconds on music. When I have midterms, the work I put into everything can be incredibly minimal. I don't know if I am really balancing it.

If we are going off the basis that I am balancing everything, then a lot of it is context switching. Especially with the nature of Lunar, a lot of the work is time sensitive, because we're either getting texts from clients or video drafts from creators where you can't block out a huge chunk of time. I could have five minutes here, two minutes here, ten minutes here. I also try to maximize the time to do something for the hour, and be productive with it. If I were to give advice to anybody that wants to learn how to better manage their time, it's less about managing your time but doing the things that you say you're going to do in the time that you allot for it. There's no real trick, you just have to do it when you say you're going to do it.

Not many people pursue these specific avenues in their career. What gives you the inspiration and courage to keep pursuing your personal path?

When people tell me I'm doing so many different things, it's weird for me because I think everything that I am doing is connected in a way. I would not have started Lunar Media or been introduced to the creator space if it weren't for music. I would not have even chosen the major that I am in if I weren't for music as well as my affinity to startups and the entrepreneurship capital. I definitely wouldn't know anything about venture capital if it weren't for music. When people ask how I keep going, I say I have seen how doing many different things work together. Everything sort of grows faster if you're doing each thing to the best of your ability, and they're all different ways you can expand your reach.

How do you plan on approaching your various career interests moving forward?

My end goal would be to have a successful startup and start my own venture fund and label. I want to invest in music tech, entertainment tech, as well as the creator economy. For the most part I really want to have my own venture fund and be able to propel the next generation of innovators, and similarly have my own label where I can do the same thing, just on a music front.

Do you have advice for undergraduates just getting into music or college?

For people getting into music, just do it. I was lucky, I had a lot of my equipment because of my Dad, but I was literally using handheld performance mics. It was a pretty decent mic, but you just need any mic. Do it, don't worry about everything being perfect because your first 5, 10 songs are not going to be great anyways. Your first 10 songs will be worse than your next 10 songs. Unless you're some kind of savant at music.

I know a lot of people that are also scared about the perception of their music by their friends or peers. I released music in 2016 as a high schooler, I don't think there was a more brutal time to do anything creative than that time. Just do it, nobody cares that much realistically, and if they do, you're probably doing something right. Make that song, release it, practice promoting it because that's incredibly important, and just do it. I'd give the same advice to anyone who wants to do anything creative. If you know this is what you want to do, why are you going to let anybody influence you?

For college, I think something that is huge is utilize your resources on campus. I think this is one of my biggest regrets. Freshman, and basically sophomore year where we had no real resources except for Zoom, office hours I used basically no resources. But when it came to junior year I really wanted to get involved on campus. I joined new clubs, Founders Illinois, Zero2One VC, even Raas Mania. Take advantage of your resources because there are so many cool people you could meet on campus. I also did Cozad. Even just going there was really, really interesting - the lectures that they had and the different workshops are super impressive and helpful. There are so many different things you could get involved in here and at any university. Even sitting at the Illini Union past a certain hour. Go to office hours. So many tutoring opportunities here. If you're using all your resources at college, there is very little reason you would not be able to succeed.

Do you ever find the plethora of opportunities constrictive?

I know a lot of people when it comes to the number of choices, it tends to scare them. But for people who are naturally people who seek and cultivate value by utilizing as many resources as possible, I think the plethora of them at Illinois is perfect for them. For a week I just wanted to learn more about fashion - I asked my TFN (The Fashion Network) friends and I went to this modeling/posing workshop around two semesters ago. Am I going to be a model? Probably not, but now I know that; I learned that I can't pose at all, but at least I tried it. The idea that I was just able to just do something that briefly came to my mind was sick. It never really overwhelms me. If I don't want to do anything, then I just won't do it. I like the idea that I can just pick and choose. You can always narrow it down yourself.


Designing in the studio

Would you see yourself at a turning point of sorts right now?

Yes. I also just started studying for the LSAT; this is the way I see law working in my favor. Right now, I am working in the creator space, but I realized enforcing certain laws and some of the legality of the creator space is really, really loose. Even things such as contracting the creator under exclusivity is pretty hard to do, especially when you don't have a lawyer that is trained in the space. I'm really interested in hopefully going to law school and working in the entertainment space for a little bit. This is hopefully pending Lunar Media being successful. But I've always been interested in getting a law degree; I like logic and reasoning which is what also drew me to economics.

In terms of the way I want to go about using my JD in a VC space, a lot of VCs have legal counsel, so I'm interested in being there and learning even more about the nitty gritty of the deals that go on. My goal is getting the knowledge that I'm really interested in having, then from there going around doing what I want to do with my career.

What are your personal and professional goals for the next few years after graduation?

I'm graduating in December. There's a buffer time where I can basically be doing anything with my life, so I have a couple options. For one of them I'd be studying for and taking the LSAT. But postgrad I'll also likely be working on Lunar Media with Jonathan, as well as music. I'm also kind of looking at and applying to a couple jobs right now, and I got reached out to join a team full-time at a startup, so I was considering that.

For my personal goal, this is going to sound funny but I've always wanted to dunk. Like dunk a basketball. That's been a dream of mine since sophomore year of high school. I've never been close. Another goal is doing a backflip. I did one in high school, but haven't done one since.

ILSURJ

FEATURES

FEATURE 1

Empowering Illinois Undergraduates: The SPIN Internship and Opportunities for Innovation

Gloria Wang

At the University of Illinois, students are always looking for opportunities to dive into the heart of innovation. There are numerous opportunities on campus to become involved in research, many of which can be found through the National Center for Supercomputing Applications. The NCSA offers fellowships and internships for Illinois students, one of which being the Students Pushing Innovation Internship Program, or SPIN.

Weiqi Zhang
SPIN Intern

SPIN supports undergraduates to be pioneers that explore the boundaries and interfaces between courseworks and real-world applications. One intern, Weiqi Zhang, works with the Molecule Maker Lab Institute (MMLI), and his involvement is a testament to how the SPIN internship turns ambitious learners into front-runners of scientific innovation.

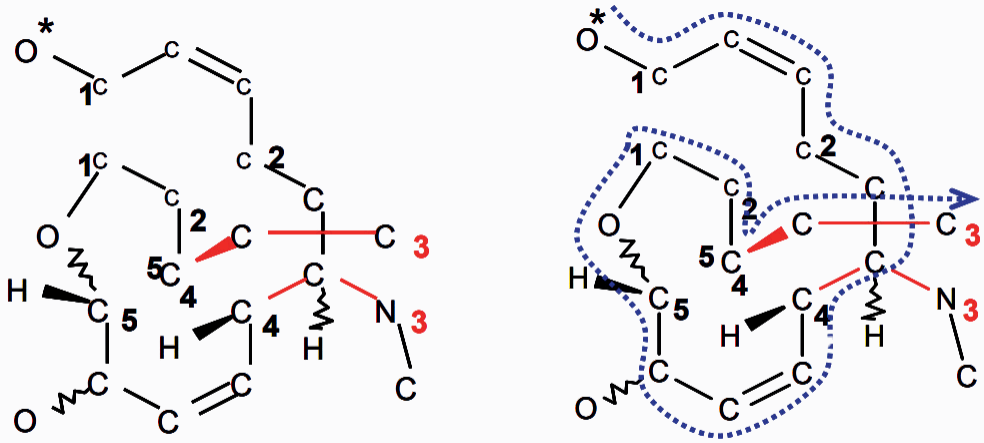
Zhang is working on cutting-edge research at the MMLI that combines organic chemistry with artificial intelligence, creating a system where chemists input molecular designs and the AI predicts synthetic pathways. This innovation streamlines the discovery and testing of new molecules. Beginning with a data ingester, the project compiles a database of chemical molecules and reactions from chemists' input, public datasets, and online databases. SMILES (Simplified Molecular-Input Line-Entry System) notation is then used to convert chemical structures into strings that are comprehensible by the computer (see pg 32); these strings can subsequently be transformed back into two- or three-dimensional representations of the molecules.

Zhang is involved in processing chemists' data so that it fits into the database schema. It is accomplished through the use of Python packages such as RDkit and PubChem's Application Programming Interface, which provides access to a vast repository of chemical compound information. As a Computer Science and Mathematics major at Illinois, Zhang has also witnessed and contributed to the successful creation of the data ingestor, a key breakthrough for the project. Now, he is on his way to integrate SMILES into a web app for chemists to retrieve and enter data. This app allows chemists to easily manage molecular data, with features for inserting, modifying, and deleting molecules from the database. He has also coded two crucial organic chemistry reactions, halogenase reaction and Suzuki coupling reaction, into the platform, elevating the app's utility in chemistry research.

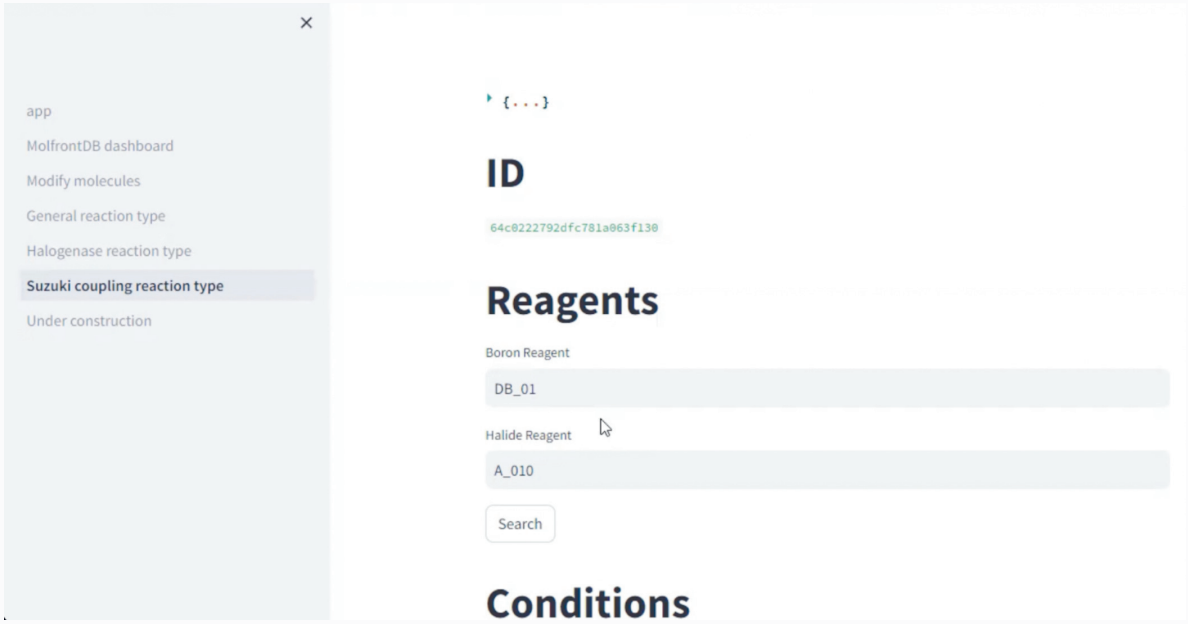
Zhang remarked that the project's difficulties are comparable in complexity to the Machine Problems he encountered in his computer science classes. He was well-prepared for the internship by having completed CS 225 (Data Structures), CS 374 (Introduction to Algorithms and Models of Computation), and CS 446 (Machine Learning) before beginning the project.

When asked how the MMLI project compared to his class experience, Zhang responded that it is not considerably more challenging than his coursework, but simply requires more labor. However, tackling real-world challenges has increased his confidence in using coding abilities outside of the classroom. Although the idea is currently in its early stages, he hopes to employ Machine Learning to eventually include AI into the system. For future applicants to SPIN, he emphasized that they should all be prepared to learn. This mindset of perpetual learning and adaptation is required for anyone seeking to make a meaningful contribution in the dynamic world of technology. In the end, he would also like to express his gratitude towards his mentors Mr. Yifang Zhang, Mr. Matt Berry, and Dr. Santiago Nunez-Corrales for guiding him through the project.

MOLECULE
MAKER LAB
INSTITUTE



Sample SMILES Breakdown For The Molecule Morphine
Notation: Oc1ccc2CC(N3C)C4C=CC(O)C5Oc1c2C45CC3
From the EPA



Interface of Zhang's App
With functionality for Suzuki couplings and halogenase reactions

Christopher Ball Bridges Technology, Sociology in Self-Designed Journalism Class and Research

Megan Harding

Assistant journalism professor Christopher Ball, Ph.D., has published research in mixed reality technologies dating back to 2019, the same year he began teaching at the University of Illinois Urbana-Champaign and designed the journalism major class "Augmented and Virtual Reality." He has four published studies, each one focusing on a social aspect associated with technology. Two of his studies explore the pandemic people's perception and acceptance of new technology like virtual reality, and the other two examine how virtual reality creates awareness about social issues, specifically environmental concerns and climate change. Ball believes that everyone in society has an important role in the emergence of mixed reality, and technology should not only be researched and developed by academics in computer science fields or major corporate players.

“I don’t want to be a part of a virtual future, or Metaverse, or whatever we want to call it that isn’t built by us,” Ball said.

Ball said he teaches these technologies specifically to journalism students, because he wants them to know that while it may seem high-tech, there are easy and affordable ways to use mixed reality as a medium of storytelling.

“I don’t want the future to just happen to my students,” Ball said. “I want them to be part of that and control where the future goes. Journalists actually have a key stake in the history of this current VR boom that we are going through.”

He wants his students to approach this technology proactively and explore the possibilities of different stories that can be told.

The University of Illinois’ investment in infrastructure, resources and creation of places where students and faculty can try out these technologies is what impressed Ball about the campus.

Recently, the University invested money in an investment for growth grant to build a center for immersive computing.

“We at U of I can be leaders in shaping where (these technologies) go,” Ball said.

Ball suggests since there are more resources than ever before, this technology should be used to enhance the classroom. This could mean creating virtual reality versions of labs to see if it helps professors teach better and benefits students.

He emphasized the importance of continued research on the production and design of technologies so that it can be made responsibly and inclusively, which will ultimately have positive impacts on the wider Champaign and Urbana communities and society as a whole.

Ball’s interest in interactive technologies blossomed when he was a child playing on the old Nintendo Entertainment System. He grew up watching science fiction, some of which featured the technology he studies today.


Christopher Ball

“I don’t want the future to just happen to my students. I want them to be part of that and control where the future goes.”

Star Trek: The Next Generation’s holodeck in particular made Ball interested in the idea of ‘stepping inside’ the television instead of just controlling it.

While completing his undergraduate program in sociology at Augusta University in Georgia, a professor of his suggested graduate school. Ball attended Clemson University for his master’s degree in applied sociology, where he used sociology to evaluate social problems.

Prior to virtual reality headsets, he partnered with an automotive safety research institute to help create a virtual desktop driver’s education program for teenagers. While he enjoyed this project, he wanted to do more. He was connected to Michigan State University as a doctoral student in the media and information studies program.

There, he focused on digital inequality and inclusion research, spending the majority of his time focusing on how to improve students' confidence and self-efficacy with technology. This also included studying video games and interactive media that help people feel more comfortable with technology.

He was given the opportunity to do a virtual reality demo with 'the Blu,' a virtual reality game that allows the player to see a whale up close underwater.

"The moment I met that whale, I felt something different than I had before," Ball said.

The demo "sealed the deal" in Ball's interest in virtual reality, and he decided that is what he wanted to dedicate his scholarship to. This very experience inspired his research examining pro-social uses of virtual reality. In 2019, he published a study exploring how virtual reality could improve scientific knowledge retention.

He published another study in 2023 using virtual reality to increase awareness about environmental issues and using virtual travel in place of physically traveling and risking harm to ecosystems. This study concluded "while the nature-based VR travel experience did not appear to influence the environmental outcome variables directly, it did indirectly affect them through the mediating roles of spatial presence and narrative engagement."

Ball feels lucky that he gets to teach what he is researching and passionate about to University of Illinois students, because it "does not always work out like that." His other two studies exploring the acceptance of virtual reality and anticipation of mixed reality 'booms' during the pandemic directly relate to how he approaches teaching in a post-pandemic world.

His adoption of VR research seems to indicate that people's perception of these technologies follow a heartbeat pattern. There are moments of hype, but people realize it is not as developed as they thought, and step back to decide how they will realistically integrate mixed reality into their lives.

With the new Apple Vision Pro release in early February, virtual reality could hit another moment of hype according to Ball, especially if Apple continues releasing new models and lowering the price for each one.

Ball said virtual reality is currently in a "make it or break it moment." Virtual reality still has its problems, but Apple's new product has the ability to make a ripple effect and convince people this is the future of communication and entertainment.

"There is an awareness that this could be big, and it is probably going to be bigger than impacting just entertainment or just the game industry," Ball said.

FEATURE 3

Gabriel Graham
Beckman Fellow

From Psychology to Neuroscience: Navigating Interdisciplinary Research at Beckman Institute

Gloria Wang

Sitting on the site of the University of Illinois Urbana-Champaign's first building, the Beckman Institute for Advanced Science and Technology is the largest and one of the most renowned research facilities on campus and in the country. Here, scientists across disciplines collaborate on research that broadens our understanding of the world. In this space, you will witness the exciting convergence of biomedicine, physics, material science, cognitive science, and other diverse disciplines, all sparking waves of innovation.

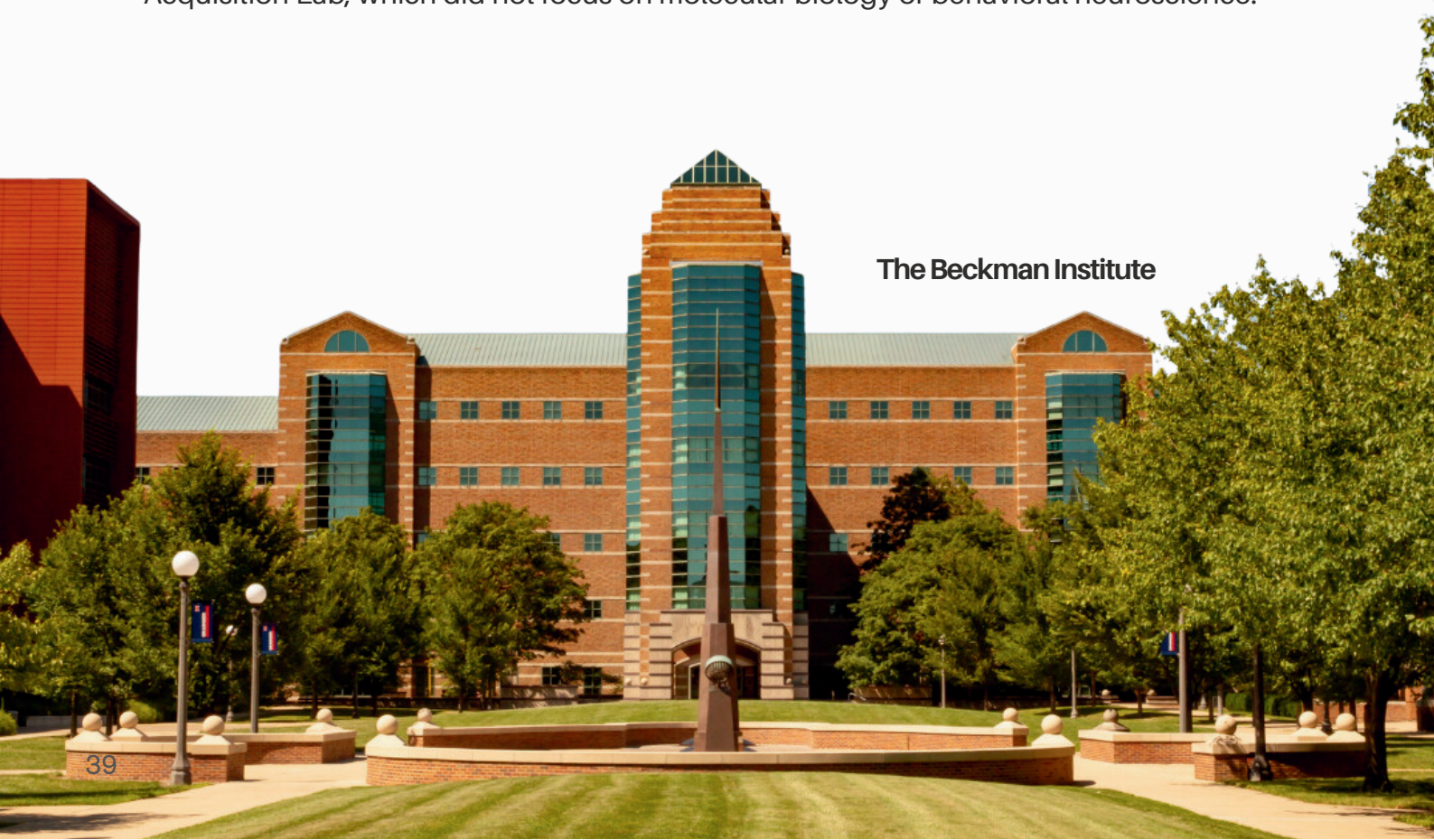
Undergraduates, too, can explore their passions through the Beckman Institute Undergraduate Fellows Program. Funded by the Arnold and Mabel Beckman Foundation, the fellowship offers undergraduates engaging in Beckman-affiliated studies an opportunity to immerse themselves in multidisciplinary research. One of the 2023 fellowship recipients, Gabriel Graham, a junior Psychology major with a minor in Molecular and Cellular Biology (MCB), represents the type of scholar the Beckman Institute seeks to nurture.

At the Beckman Institute, Graham's project centers on the neuroplasticity of fish, a topic that bridges behavioral neuroscience, genetics, and ecological physiology. His research aims to understand the mechanisms behind sex change in clownfish. By modifying genes, his team hopes to observe how the brain orchestrates a complete transformation from male to female. This method provides essential insights into how external stimuli are integrated to facilitate changes in neurobiology, also known as neuroplasticity. A better understanding of how neuroplasticity is controlled may lead to new treatments for various neurological disorders in humans.

To accomplish this, Graham is individually responsible for breeding and maintaining a transgenic clownfish line and designing behavioral assays to test when behavioral sex change occurs during clownfish development.

"I am working directly with the P.I. (Principal Investigator) like a graduate student," he shared. Being at the helm of the project has taught him invaluable lessons in self-reliance, time management, and making decisions that directly affect the outcome of their studies — skills that are crucial for any researcher.

Perhaps most inspiring is Graham's leap into a field that was somewhat unfamiliar to him. Coming to the Beckman Institute, he had only collected data for the Language Acquisition Lab, which did not focus on molecular biology or behavioral neuroscience.



The Beckman Institute

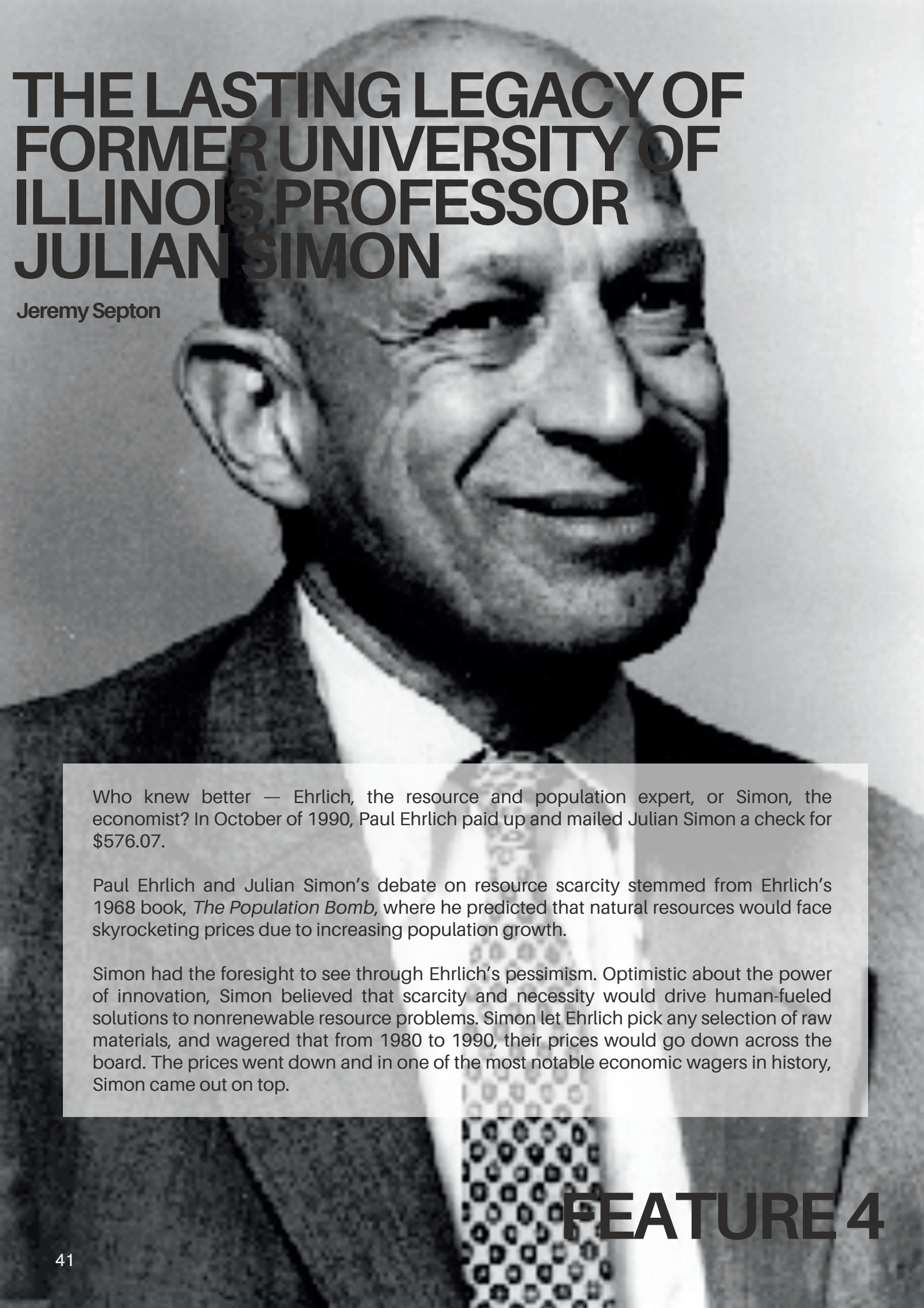
To apply for the fellowship, a research proposal is required to be written and submitted by the student. Graham's suggestion to prospective students working on proposals is to look for sub-experiments inside the larger studies or to address one question from an earlier project. He also highlighted the value the Beckman Institute places on interdisciplinary research, which he featured in his own research proposal.

Aspiring to enter a neuroscience Ph.D. program, Graham added that his time at Beckman "has prepared him for his future goals more than any class." He is still working at the Beckman Institute, planning to publish his own manuscript by this summer.

From his journey as an undergraduate with a background in psychology to leading a neuroplasticity project at a world-renowned research facility, Graham embodies growth fostered by the Beckman Institute Undergraduate Fellows Program. His journey underscores the value of working in an interdisciplinary research environment. At the Beckman Institute, crossing traditional academic boundaries is not just encouraged, but is a pathway to groundbreaking discoveries and personal development.

THE LASTING LEGACY OF FORMER UNIVERSITY OF ILLINOIS PROFESSOR JULIAN SIMON

Jeremy Septon



Who knew better — Ehrlich, the resource and population expert, or Simon, the economist? In October of 1990, Paul Ehrlich paid up and mailed Julian Simon a check for $576.07.

Paul Ehrlich and Julian Simon's debate on resource scarcity stemmed from Ehrlich's 1968 book, *The Population Bomb*, where he predicted that natural resources would face skyrocketing prices due to increasing population growth.

Simon had the foresight to see through Ehrlich's pessimism. Optimistic about the power of innovation, Simon believed that scarcity and necessity would drive human-fueled solutions to nonrenewable resource problems. Simon let Ehrlich pick any selection of raw materials, and wagered that from 1980 to 1990, their prices would go down across the board. The prices went down and in one of the most notable economic wagers in history, Simon came out on top.

FEATURE 4

You may not have heard of Julian Simon or the Simon-Ehrlich wager, however, you're certainly familiar with at least some of Simon's ideas whether you know it or not. Airlines used to bump passengers off overbooked flights at random. In a system first suggested by Julian Simon, airlines now let willing passengers auction their seat back to the airline in exchange for travel vouchers or upgrades, meaning only willing passengers give up their seats on overbooked flights (Neal, 2002).

Julian Simon was a professor at the University of Illinois from 1963 to 1983, a Senior Fellow at the Cato Institute, and author of many books, professional publications, and articles. Thought of as a maverick by many, Simon is known as a founder of free-market environmentalism and one of the most influential scholars on population, natural resources, and human ingenuity.

His 1981 seminal work, *The Ultimate Resource*, challenges conventional wisdom by asserting that the enduring intellect of humanity will triumph over any challenges posed by resource scarcity. This magnum opus reflects the unwavering conviction in Simon's ideas and innovative thinking that leaves him an everlasting legacy.

In honor of the great economist, the University of Illinois has sponsored two Julian Simon Faculty Fellows, Professor of Finance Nolan Miller and Professor of Finance Rustom Irani. We had the honor of speaking to Professor Rustom Irani for this piece, who shared his knowledge and view of Simon's life.

Like many, Professor Irani was largely unaware of Simon's relationship to the University, "I was very blessed and very fortunate to be offered this faculty fellowship, and at that point, you know, I saw and heard the name Julian Simon. I didn't at the time that he was affiliated with the University of Illinois."

Professor Irani, however, knew of the Simon-Ehrlich debate and the sharp contrast between Julian Simon and Paul Ehrlich. Ehrlich had "ideas which are inherently very pessimistic." Simon, "was much more of an optimist" through his strong beliefs in "the idea of human ingenuity and the ability to overcome whatever challenges there were when it came to population and technology." The monetary bet between the two was something Professor Irani learned later.

On Simon's relative obscurity Professor Irani said, "I don't think many people or as many people are aware of, you know, his history and contributions that should be for whatever reason." For someone dubbed by Fortune Magazine as among "the world's most stimulating thinkers" (Simon, n.d.), a Nobel Laureate in Economics, and Friedrich von Hayek's self-proclaimed "intellectual son" (Neal, 2002), Julian Simon's legacy has gone under the radar. It is certainly worth taking a moment to acknowledge the inherently optimistic philosophy behind the idea that mankind can work to overcome almost any scarcity and reading up a little bit on one of the University of Illinois's most influential historical faculty.

Thank you to Professor Rustom Irani for generously offering his time for this interview.

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Neal, L. Julian Simon as Economist. (2002). https://web.archive.org/web/20040215153827/http://www.business.Illinois.edu/publications/News/2002/April.SimonTribute.pdf
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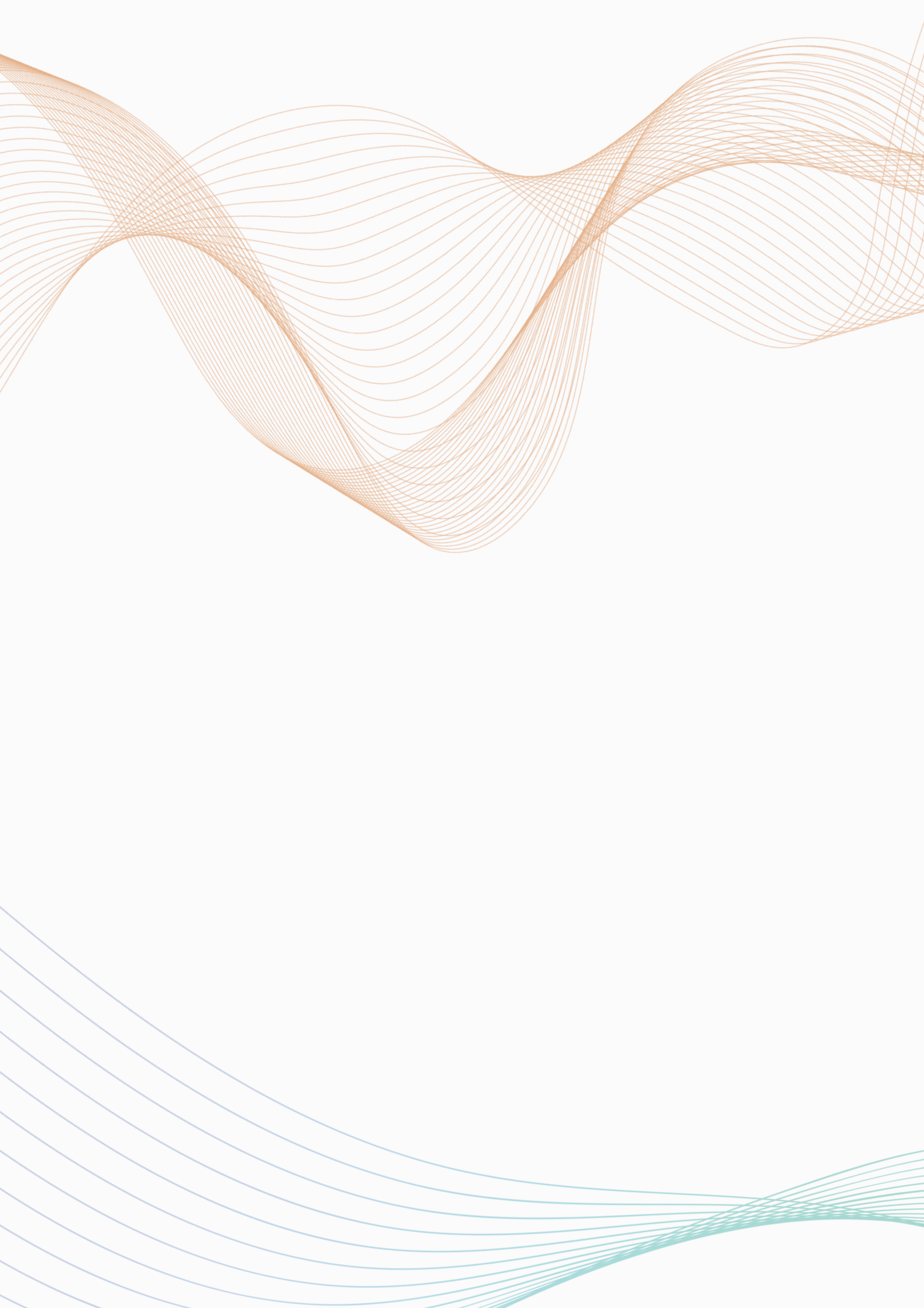
"The main fuel to speed the world's progress is our stock of knowledge, and the brake is our lack of imagination."

~ Julian Simon



ILSURJ

RESEARCH ARTICLES

CYTOCHROME C IMMOBILIZATION ON INDIUM TIN OXIDE FOR BIOSENSORS

Healey Kogan,[1] Valter Zazubovits[2]

1: Department of Physics, University of Illinois Urbana-Champaign
2: Department of Physics, Concordia University – Loyola Campus

Abstract

Biosensors are becoming ubiquitous in medicine and environmental science. They incorporate biological processes and physicochemical detectors to provide enhanced detection capabilities. The biosensors we plan to develop rely on bacterial reaction centers. These centers bond readily with cytochrome c, which is an electron transporter protein. However, cytochrome c does not bond readily to physical devices. Thus, part of this project involved studying the immobilization of cytochrome c on indium tin oxide surfaces. In this work, we demonstrate several methods and devices used to study cytochrome c. We ran cyclic voltammetry and spectrophotometry tests to demonstrate that cytochrome c can exchange electrons with our indium tin oxide coating to create a circuit for the biosensors. Indium tin oxide was used because it is a transparent, conductive substance. The indium tin oxide's transparency allows us to take images through the indium tin oxide, and the conductivity allows for the transfer of electrons. We also modified our optical setup. While the previous setup relied on confocal lens induced confinement microscopy, the new setup has parallel indium tin oxide surfaces with tunable gaps and parallelism controlled with interferometry. Based on these findings, further work will be dedicated to developing an apparatus for adsorbing the cytochrome c to indium tin oxide.

Introduction

Biosensors that detect herbicides, explosives, or heavy metals will improve current environmental safety tests, terrorism prevention, crime scene investigation, and the decontamination of ammunition production plants by increasing the sensitivity and efficiency of testing for harmful chemicals. Currently, the most important goal is to develop biosensors that can easily be used in the field and do not require large equipment or precise environmental conditions[1] . These biosensors will utilize bacterial reaction centers (BRCs) from single-cell organisms in which exposure to analytes will inhibit primary electron transfer in photosynthesis performed by these bacteria. When the electron transfer is inhibited, the circuit of the biosensor will be broken, and no signal will be detected. The lack of signal will indicate the presence of undesired chemical substances. The chemical structures of several explosives, such as nitrophenol or RDX, are similar to the chemical structures of herbicides, so the explosives would attach to the quinone binding site on the BRC and inhibit the electron transfer and interrupt the signal in an electrical circuit. There are currently no biosensors that are portable and can also detect nanomolar-scale amounts of chemical substances[1]. Since BRCs are several nanometers in size, they are extremely movable and millions of them can fit on one microscope slide. Therefore, the large amount of BRCs over a small area makes a highly sensitive, portable biosensor. BRCs have been immobilized on gold for photovoltaic devices or to detect herbicides[2]. The Zazubovits group had previously demonstrated the detection of TNT and picric acid using BRCs immobilized on gold[3]. However, work has not been done yet on using ITO electrodes with BRCs to combine photoelectrochemistry and spectroscopy to detect explosives.

To work with BRCs, one must first design an apparatus to immobilize them and control the electron transport through them. No procedures have been published detailing how to immobilize BRC onto ITO, so we worked instead with an intermediary protein, cytochrome c (cyt c) which is known to attach in a specific configuration to the BRCs. There are several papers[4,5,6] reporting the successful attachment of cyt c to ITO. This project focuses on trapping cyt c physically on indium tin oxide (ITO) in a more efficient and reproducible way than what has previously been published[4,5,6]. The ITO will then be connected to sensors that will read out the current flowing from a circuit made up of the BRCs, cyt c, and ITO. A drop in current will indicate a broken circuit and the detection of the analyte. The end goal of this project is to combine these processes together to trap cyt c and eventually combine it with BRCs in a biosensor.

Cyt c is a water-soluble protein allowing for it to be stored in a solution. This solution can then easily be pumped into and out of a biosensor, enabling precise control of cyt c concentration within the biosensor. Additionally, cyt c has reversible reduced and oxidized forms that readily transfer electrons[7] leading to a low resistance circuit component.

ITO is a transparent semiconductor that can be deposited onto glass in nanometer-thick films. By being both transparent and conductive, ITO can be used as a circuit component that also allows for light to pass through it. ITO-coated glass is sturdy and connects readily to a larger circuit by attaching wires. Since the goal is to measure BRC photosynthesis, light must be able to reach the BRCs, which can be accomplished by using a transparent semiconductor, such as ITO[8]. Currently, ITO is used for biosensors in laboratory environments on small scales[9]. We aim to develop a biosensor that can be used in outdoor conditions and on larger scales.

While cyt c has been trapped on ITO before[4,5,6,7], our goal is to use a new technique that does not implement gold[10] where we induce trapping by flooding a cell with cyt c solution, and then removing that solution through tubes. These tubes can then be used to flood the cell with water to wash away cyt c and restart the experiment. Also, we aim to bring bring the ITO pieces that

make up the cell extremely close together in a controlled fashion, so the electron carriers in the solution will have as little distance to diffuse as possible. Consequently, we are hoping to design a new technique that will allow for the ability to run many experiments with one biosensor before having to use a new one. Previous experiments could not be reproduced with the same materials[7,9], so our approach would eliminate waste and expedite the biosensing process.

To meet our goal, the experiment is split into two focuses—electrochemistry and microscopy. The electrochemistry component consisted of cyclic voltammetry experiments, cleaning processes, and adsorption processes. These methods were implemented to detect the ability for cyt c and ITO to exchange electrons and complete a circuit. The microscopy component consisted of designing and building devices to create sample cells and properly aligning these cells. The microscopy section focused on imaging the cyt c to understand its absorption patterns and its interaction with ITO. Because of unexpected issues, we were unable to combine the two parts together as planned.

Methods

Electrochemistry:

Cyclic Voltammetry: We used cyclic voltammetry to test whether cyt c attached to ITO-coated pieces of glass. Each piece of glass was 170 µm thick with a layer of ITO evaporated on the entire area of one side to a thickness of 20 nm. A conductor, either a wire or a metal clip was attached to the ITO to extend the circuit. A voltage difference is created in the solution between two electrodes: the working and the counter. A third electrode, the reference, is added to serve as a reference voltage. Current flows from the working electrode into the solution and out through the counter electrode. The current flow measured by the counter electrode depends on how many free electrons are in the solution, so we can observe when reduction and oxidation reactions are taking place. The voltage difference is cycled from negative to positive and then back again for three full cycles. During each cycle, cyt c undergoes a reversible redox reaction, transforming between its oxidized form, ferricytochrome, and its reduced form, ferrocytochrome. When the voltage difference is low, electrons flow from the cyt c to the solution producing the oxidized form ferricytochrome and increasing the number of free electrons in the solution. When the voltage difference is high, electrons flow from the solution to the cyt c producing the reduced form ferrocytochrome and decreasing the number of free electrons in the solution. The counter electrode measures the current flowing through it. The current increases as the number of free electrons in the solution increases. However, if there are too many free electrons, they start to block each other from leaving through the electrode, so the current decreases. Then, as the number of free electrons decreases to a point where they are no longer saturated, the current increases again. Finally, when there are too few free electrons, the current decreases again. This change in current is measured by the cyclic voltammogram (CV) as the voltage is varied to produce several of these cycles. The literature[6,12] suggests that the current peaks for immobilized cyt c should occur at around 50 mV and -50 mV with respect to the silver/silver chloride (Ag/AgCl) reference electrode[4,5,6] . Thus, we designed and carried out similar experiments to test if we observed the same results. Cyclic voltammetry requires the use of a working electrode, reference electrode, and counter electrode. We ordered new electrodes and ran experiments to find the best combination of the three different electrodes. The best reference electrode was the CHI111 Ag/AgCl electrode, and the best counter electrode was the CHI115 platinum (Pt) wire electrode as shown in Figure 1. We tried using a Pt sheet for the counter electrodes because a larger surface area yields less resistance, which would improve current flow. However, the Pt sheet electrode appeared to be made from insufficiently pure Pt. Thus, we used the Pt wire as the counter electrode. To test

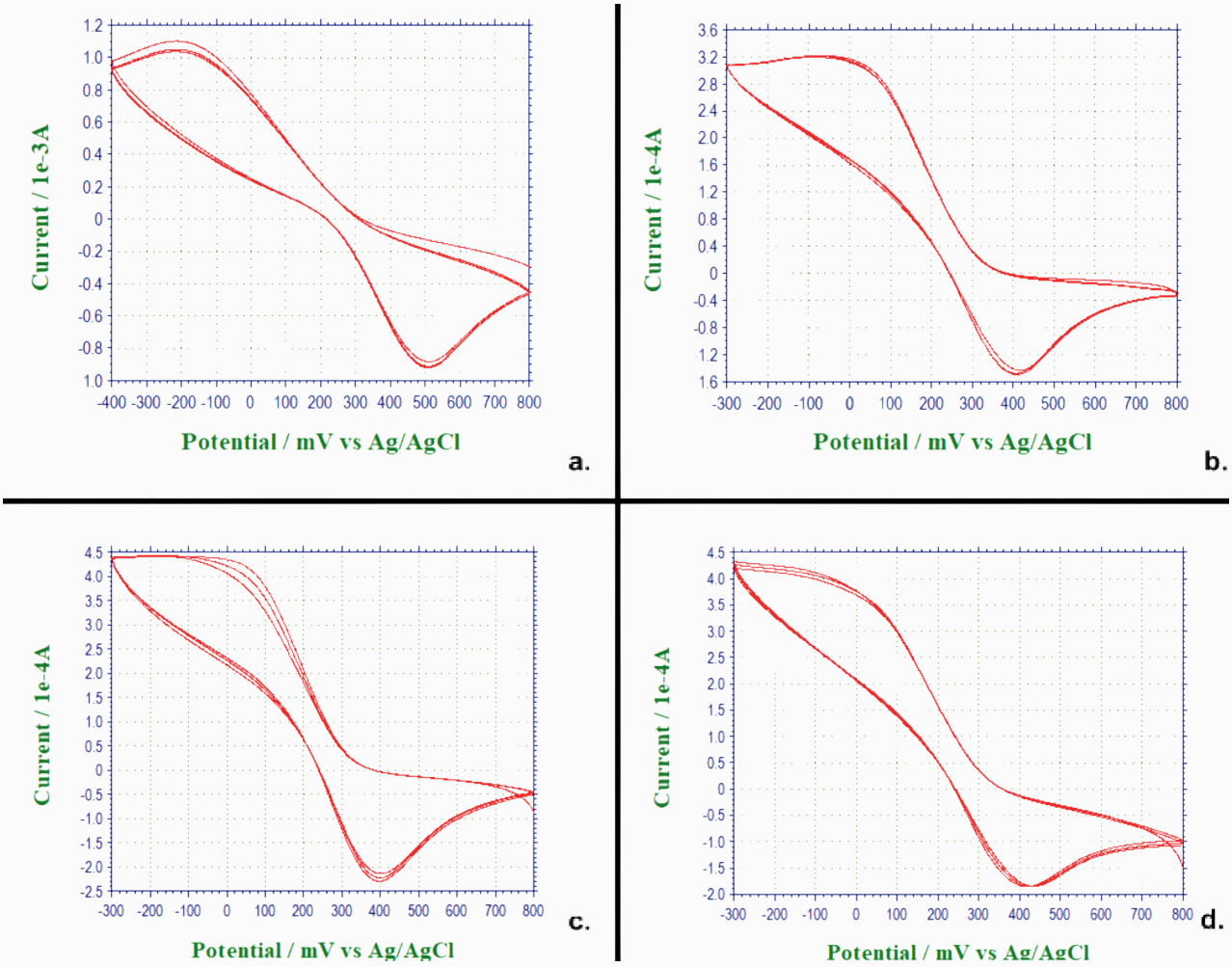


Fig. 1. CVs of different reference and counter electrodes. The four CVs were taken in a solution of 0.2 M KCl and 0.01 M K3[Fe(CN)6]. Cyt c was not included in this solution, so the peaks should be around 100 mV and 300 mV11 . They were run at a scan rate of 0.01 V/s from –0.3 V to 0.8 V. The working electrode was ITO-coated glass that was cleaned by wiping the ITO with acetone, deionized water, methanol, and then deionized water. The reference and counter electrodes were varied between the four runs. (a) Reference CHI111 Ag/AgCl; Counter CHI115 Pt wire (b) Reference R0305 Ag/AgCl; Counter P211 Pt foil square (c) Reference R0305 Ag/AgCl; Counter CHI115 Pt wire (d) Reference CHI111 Ag/AgCl; Counter P211 Pt foil square. After these tests, we continued to use the CHI111 Ag/AgCl reference electrode and CHI115 Pt wire counter electrode because they exhibited the clearest peaks that were close together.

whether the electrodes and the cell were functioning correctly, we initially used a gold working electrode because of its consistent, accurate performance. However, our goal was to use ITO-coated glass as the working electrode and test cyt c adsorption on the ITO using cyclic voltammetry. To test the performance of the cell and the electrodes we also performed cyclic voltammetry with a 0.01 M ferricyanide solution, which has well-known and stable responses. Before exploring adsorption of cyt c onto the ITO electrodes, we first performed cyclic voltammetry on cyt c in solution.

While we used a Ag/AgCl reference electrode, some papers[6,12] reference their voltage choices with respect to the normal hydrogen electrode (NHE). These papers use a Ag/AgCl reference electrode in their experiment but report their data with respect to an NHE. The NHE is an ideal reference electrode that is rarely used in experiments, while the Ag/AgCl reference electrode is one of the most used reference electrodes. The Ag/AgCl reference electrode potential compared to the NHE is 0.23 V. Thus, any voltage values given with respect to NHE can be converted to voltage values given with respect to the Ag/AgCl electrode by subtracting 0.23 V.

In both cyclic voltammetry and spectrophoto-

metry, ITO-coated glass serves as the working electrode. ITO is a transparent conductive material ideal for serving as an electrode that also allows for cell imaging. The transparent quality enables microscope images to be taken of the interior of the cell and spectrophotometry tests of the cell to be run. As an electrode, the electrons from the cell solution can pass through the cyt c and then across the ITO, which generates a measurable current during cyclic voltammetry. Several papers have shown successful trapping of cyt c on ITO[4,5,6,12] . However, their experiments lacked repeatability and reuse of materials. Therefore, we aim to develop a method that allows us to control when cyt c is trapped and released from ITO repeatedly by implementing a flow tube for the addition and removal of cyt c solution into the ITO-coated sample cell.

Cleaned ITO-coated glass produces better results, as shown by steeper peaks that are spaced closer together in the CV, than uncleaned glass. Hence, glass preparation must include a rigorous cleaning process. Many recipes for cleaning ITO-coated glass exist[4,5,6] , but they all have in common the use of organic solvents, distilled water, and a sonicator. After trying several recipes, the most effective recipe involved five-minute sonications each of a detergent (2% Alconox or 2% Triton-X), 95% ethanol, and two rounds of water. This cleaning was the best because following it, the ITO produced the sharpest peaks during the CV. The cleaned ITO-coated glass was then left in 10 mM or 5 mM phosphate buffer overnight to equilibrate before being used in either cyclic voltammetry or spectrophotometry. The 5 mM phosphate buffer had a lower ionic strength than the 10 mM buffer, so there were less ions in the buffer that would want to attach to the cyt c and detach it from the ITO. Pieces of glass kept in 5 mM phosphate buffer had sharper peaks that were spaced closer together than those stored in 10 mM phosphate buffer.

Once prepared, the ITO-coated glass must be glued to the body of the cell for use. Two processes were followed to produce a macroscopic spectroelectrochemistry cell and to produce a microscopy cell in a convex lens-induced confinement configuration. The current process of gluing the ITO for the macroscopic cell involves using gaskets made of double-sided tape. First, we glue a gasket to the body of the cell and apply heat and pressure for about 5–10 minutes. Then, we add the first piece of ITO-coated glass with the ITO facing into the cell and apply the same heat and pressure as before. We then followed the same procedure to add a second piece of ITO to the opposite side of the cell.

A similar process was used for the microscopy cell. However, the second gasket is added directly on top of the first ITO piece. This gasket has channels for fluid flow to fill the cell with the cyt c solution. We finally add the last piece of ITO-coated glass with the ITO also facing into the cell. The glass pieces are fragile, so they must be placed gently to prevent any cracks. They also must be glued shifted from each other to ensure access to both ITO surfaces, so they can be used as electrodes. This configuration was eventually changed to a single piece of ITO, so only one piece was glued on as described in the Microscopy section.

Once the experiments are completed, ITO-coated glass can be unglued and reused. The pieces of glass must be soaked in acetone for several hours, and then gently pushed off to prevent the pieces from cracking. The ITO-coated glass must be thoroughly cleaned again before being reused.

After the electrodes and proper voltage values are chosen and prepared, blank scans must be run. These scans serve as a comparison point for CVs that use cyt c solution. The blank scans must be taken before adding cyt c solution to prevent any potential contamination. The blanks use a cleaned ITO-coated glass working electrode in a phosphate buffer solution. This solution has the same molarity as the cyt c and phosphate buffer solution that will be used in the experiment. The blank results are subtracted from the experimental results to obtain the relative CV. The voltage range and

scan rate must be kept the same for the blank scans and experimental runs.

The molarity of the cyt c and phosphate buffer solution plays a significant role in trapping cyt c on ITO-coated glass. The solution must be kept at a constant pH value, which is maintained by the phosphate buffer. However, cyt c may detach from the surface if ionic strength is too high. Thus, the buffer must be kept at a molarity less than or equal to 10 mM. In addition, a higher concentration of cyt c provides greater chances for adsorption, and a molarity of 50 μM of cyt c is a high enough concentration for cyclic voltammetry. However, the molarity of the cyt c solution must be reduced to 15 μM for spectrophotometry experiments; otherwise, the 400 nm absorption band is too high, so its peak absorption is not reliable. Koller and Hawkridge[12] found that oxidized ferricytochrome attaches more readily than reduced ferrocytochrome. Adding a few pieces of potassium ferricyanide ($K_3[Fe(CN)_6]$) can aid in oxidizing cyt c and producing greater quantities of ferricytochrome. Consequently, this small amount of $K_3[Fe(CN)_6]$ may increase the chances of trapping cyt c to ITO. More research needs to be done on the effectiveness of adding $K_3[Fe(CN)_6]$ to the solution, since we did not see any change in cyt c trapping results. Altogether, the final cell solution should consist of less than or equal to 10 mM phosphate buffer, 50 μM cyt c, and potentially a small amount of $K_3[Fe(CN)_6]$.

To study adsorption of cyt c to ITO, we ran electrochemistry tests using different cleaning procedures and solutions. Any form of cleaning of the ITO-coated glass pieces improved results, but we did not see any significant difference between the different cleaning methods. We found that either wiping the glass with organic solvents or sonicating the glass in a solution of organic solvents worked consistently. Leaving the glass pieces in solution overnight led to the cyt c detaching as evidenced by the lack of current peaks in CVs following this procedure, so we incubated the pieces in the solution for a maximum of four hours. We then reduced the phosphate buffer molarity to 10 mM and increased the cyt c molarity to 50 μM. This solution showed clear, peaked CV curves, and we saw even more pronounced CV curves when we lowered the ionic strength of the phosphate buffer by decreasing its molarity to 5 mM. Thus, we concluded that the best solution for cyclic voltammetry is 5 mM phosphate buffer with 50 μM cyt c. The CV curves were observed qualitatively since the important results come from comparing the shapes of the curves with respect to the voltage rather than magnitude of the current values because those can vary based on the size of the cell.

Spectrophotometry: Spectrophotometry is an additional way to test for cyt c immobilization. We used it to measure the optical absorbance of the cell. If cyt c were to attach to the ITO-coated glass, then some cyt c absorption would be visible even after removing the cyt c solution and replacing it with clean buffer. The absorption results would match cyt c absorption results found in papers[5,6].

These experiments were conducted in a homemade photoelectrochemical cell. The cell is shown in Fig. 2. It is 6 cm high and 1 cm thick, so it can fit easily in a spectrophotometer. It had three holes—two for the counter and reference electrodes, and the third for the ITO electrodes, which served as the working electrode. Wires were attached to the ITO pieces and then those wires were connected to each other to act as one electrode. Both sides of the hole for the ITO electrode were covered by gluing ITO-coated glass. Wires were then glued by electrical paint to the ITO. The cell was filled with solution through the top holes before the counter and reference electrodes were added. Instead of performing cyclic voltammetry, different voltages were continuously applied to the cell for around 10 minutes each. We had issues with the solution dissolving the electrical paint and causing the wires to detach and break the circuit. Therefore, we need to develop a waterproof method for connecting the wires to the ITO. Additionally, the process of gluing the ITO to the cell was not perfect, causing leaks that were then glued shut.

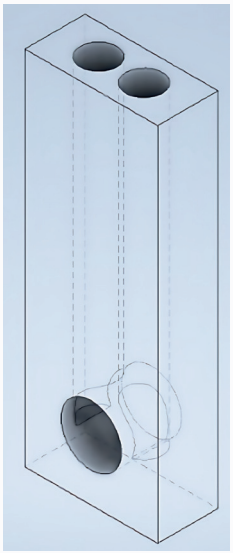


Fig. 2. Technical drawing of cell with through hole to allow for spectroscopy measurements. The two top holes are for the reference and counter electrodes and the bottom through hole is for coating ITO-coated glass.

Similar to cyclic voltammetry blank scans, baselines serve as comparison points for experimental data. Baselines are taken using phosphate buffer solution as the medium. Cyt c must not be introduced until after baselines are taken to prevent contamination.

While a constant voltage was applied to the cell, a laser beam was sent through the cell. The laser beam decreased in wavelength incrementally at 0.1 nm/s from 700 nm (red visible light) to 300 nm (ultraviolet). The spectrograph measured how much light exited the cell in comparison to how much light entered the cell and recorded this absorption value from zero, meaning no absorption, to one, meaning complete absorption. We ran these experiments with the same ITO pieces several times and cleaned them in between by filling and emptying the cell with organic solvents. We replaced the cyt c solution daily and followed the same solution procedures as described for cyclic voltammetry. Only preliminary tests were performed using the spectrograph, so more need to be run to fully understand the electron transfer process in our cell.

Microscopy:

Convex Lens: Convex lens-induced confinement (CLIC) microscopy is the process of using a convex lens to push down on the top piece of a cell, trapping the sample in place. Because of the convex shape of the lens, the sample becomes more trapped at the center with less trapped sample farther toward the edge. CLIC microscopy has been used successfully to trap and stretch DNA[13]. Thus, we predict that CLIC microscopy can be used to trap cyt c and BRCs.

We designed a CLIC device based on a lever system with a piezo[14] as a fine adjustment tool as depicted in Figure 3. On one side, a piezo rests between the bottom of the device and the lever. On the other side, the lens rests at the bottom followed by a rod on top. The rod is held up by a spring and pushed down on by the lever. Below the lens, the cell is attached. The cell is made as described above involving two pieces of ITO-coated glass. The two pieces of glass serve as working electrodes. As electricity runs through the piezo, it expands, pushes on the lever, and causes the lens to push down on the cell containing the sample. We had several issues with this device, including ITO-coated glass pieces breaking easily and the lens not pushing down directly in the center.

Testing this device involved running a raster

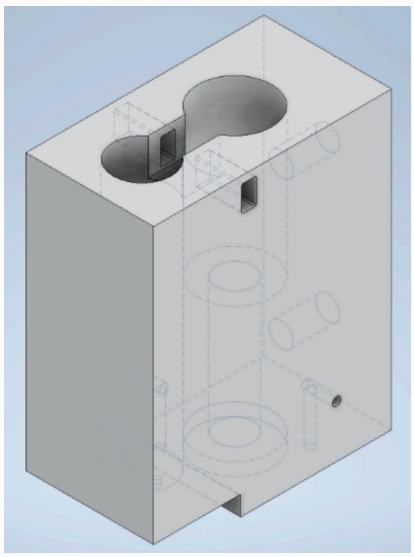


Fig. 3. Technical drawing of cell holder for CLIC microscopy. The piezo would lie in the hole on the left and the rod would lie on the hole to the right having the lens at the bottom.

raster scan of the sample cell filled with fluorescent solution. This scan moves the sample in fixed increments across the focal plane of the microscope objective and records the photon count at each measurement point. The results provide information about the shape of the cell. The data obtained from the scan is mapped on a 3D graph with the brightness plotted on the z-axis. CLIC microscopy should yield a scan with a shape similar to a spherical indent.

Flat Glass Piece: Since the CLIC microscopy was not providing replicable results, we switched to a new approach of using two parallel flat pieces of glass. These pieces must be exactly perpendicular to the laser beam and parallel to each other. The flat glass approach ensures that there is a constant, shorter distance between the electrodes. This setup would guarantee that the distance that soluble electron mediators would have to travel from a BRC-coated electrode to another electrode is constant and known. This approach also provides easier access to the cell, easier handling (less breaking of ITO-coated coverslips), and better reproducibility. Before attempting electrochemistry or protein immobilization experiments in this cell, its optical design must be tested. For that purpose, the bottom glass is a thin coverslip coated with ITO, while the top glass is a sturdier sapphire piece (not yet coated with any conductive material). The bottom glass is glued to the bottom of the cell with the ITO facing the sapphire. The sapphire hangs suspended from a tilt mount, which adjusts the sapphire until it is perfectly parallel to the bottom glass. A coarse adjustment differential screw z-axis mount and a fine adjustment piezo push the sapphire down toward the bottom glass until only nanometers separate the two pieces and create a cell. This cell can then be used for imaging with the microscope. The ITO-coated glass can serve as a working electrode for electrochemistry experiments. All pieces are connected by rods in a cage system. This design currently has some issues with keeping all of the pieces sturdy and aligned with each other during use and adjustment. These make it difficult to obtain repeatable results.

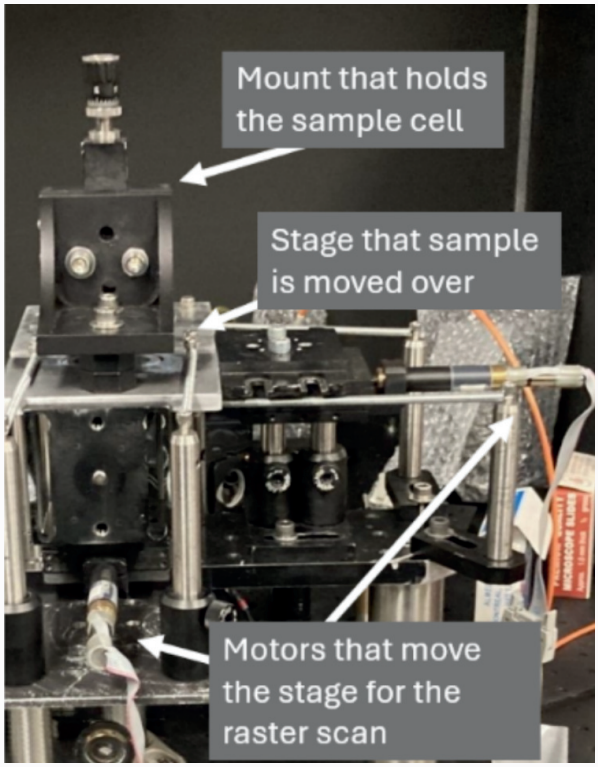


Fig. 4. Optical setup for the microscope. The components were attached vertically on the left part of the image. The raster scan was enabled by two motors shown on the right and bottom left of the image shown in gray.

Aligning the two glass pieces perfectly is crucial for electrochemistry experiments to work properly. The ITO-coated glass piece is aligned when the laser beam reflected from it is superimposed back onto the incident beam. The sapphire piece is aligned when the reflection of the sapphire matches the reflection of the ITO-coated glass. If the pieces are aligned correctly and are both flat, adding an additional lens to the incident beam path will make interference patterns visible. These interference patterns arise from the superposition of the two reflected beams —one from the sapphire piece and one from the ITO-coated glass. Perfect alignment results in a single-focus Newton's ring interference pattern.

Results and Discussion

Cyclic Voltammetry: Our CV results did not always match the literature[5,6]. Most of the time, the results differed by current peaks being shifted by a constant voltage value or

or the peaks having a greater than expected voltage difference. The constant voltage shift arose from the reference electrode, which may not have the same constant voltage difference with respect to the NHE. This shift did not affect the analysis of whether cyt c attached or not. Larger than expected peak separation indicates the electrolyte resistance was too high, which may have arisen from two factors—the cell size was too large and created higher chances for electrons to diffuse and not complete the circuit or dirty electrodes that prevented efficient chemical reactions. We noticed that using a cell size of 1 ml rather than 10 ml improved cyclic voltammetry results. In addition, the peak current should not depend on scan rate for the reversible redox reaction the cyt c undergoes during a scan. However, if the peak current is linearly proportional to the square root of the scan rate, then a homogeneous irreversible reaction occurred. If any irreversible reaction occurs, then the cyt c and ITO are no longer in their original states, so they can no longer interact as intended. Thus, if an irreversible reaction occurs, the experiment must be cleaned and restarted. Avoiding these reactions is necessary to create a reusable biosensor.

Cyclic voltammograms provide information on the electron transfer reactions occurring in the cell. Since the cell contains cyt c solution, a CV with sharper peaks would indicate that the cell and solution are working properly. Adsorption of cyt c is proven if the solution is washed away and the CV peaks still exist. As a result, more tests must be taken to ensure that the cyt c is trapped. Spectrophotometry provides more data to prove whether the trapping was successful. If the cyt c is trapped, after replacing the solution, the absorbance should still contain the characteristic peaks of cyt c. With both the CVs and absorbance graphs, one can claim with greater certainty whether the cyt c attached to the ITO-coated glass or not. As described in the Methods section, CVs are evaluated by comparison, rather than by raw data. Therefore, we checked for a similar pattern to what we saw in the literature[6,12]. We looked for distinct peaks close together, which represent the redox reaction that converts between ferricytochrome and ferrocytochrome. We observed these desired peaks after using a cleaning procedure of sonication with detergent, ethanol, and two rounds of water and using a Ag/AgCl reference electrode and Pt wire counter electrode. However, these experiments were not reproducible, so we aim to develop a cleaning method and electrode combination that will provide us with the desired reproducibility.

Spectrophotometry: We used the spectrophotometer primarily in combination with holding the cyt c solution at a constant voltage by using the cell design shown in Figure 2. This constant voltage run, if successful, will result in either the oxidation of cyt c into ferricytochrome at high voltages or the reduction of cyt c into ferrocytochrome at low voltages over time. Thus, these reactions show that the cyt c undergoes redox reactions freely, which is important for transferring electrons. Absorbance graphs that show these results, in addition to CVs with clear peaks, increase our confidence that the cyt c is exchanging electrons properly with the electrodes. At a low voltage of -0.2 V and a wavelength of 537 nm, we saw a bump in the absorption spectrum, which is unique to ferrocytochrome, indicating its presence in the solution. Additionally, when we raised the voltage to 0.4 V, the bump decreased, indicating a reduction in the amount of ferrocytochrome and an increase in ferricytochrome. These graphs looked similar to those found in previous work[4]. I only performed preliminary tests, so more work must be done to ensure that the ferricytochrome and ferrocytochrome are behaving as desired in our cell. Also, since these were preliminary tests, we looked more at the qualitative aspects of whether the peaks occurred at similar wavelengths to those shown by Collinson and Bowden[4]. We will record numerical results once we have guaranteed repeatability and that we are observing cyt c rather than any other analyte.

Convex Lens: For the convex lens setup, our results showed a two-dimensional tilt in the x-y plane and no indent. Thus, we were unsuccessful in producing CLIC microscopy

using the lens in the device we designed. Because of this result, we switched to a new method involving two flat pieces of glass.

Flat Glass Piece: As mentioned above, proper alignment of the cell with parallel surfaces should result in the emergence of Newton's rings interference patterns. Currently, we observe a nearly symmetrical picture with four foci. Therefore, we believe that the bottom ITO-coated glass piece is warped and becomes bent during the process of gluing it with gaskets. Since the glass pieces are 170 µm thin, they are very fragile and malleable, and any slight tension can bend them permanently. Consequently, new attachment methods must be considered to prevent warping the glass pieces. Furthermore, the top glass piece requires even finer tilt adjustment, which can be obtained by using screws with greater threads-per-inch values. While the flat glass piece design has improved results, many improvements involving stability and fine adjustment must be made.

Conclusion

Overall, this project aimed to immobilize and observe cyt c on ITO-coated glass. The project was split into physically trapping cyt c from solution and improving the electrochemical cells that will eventually contain the transparent electrodes covered with cyt c and BRCs. The electrochemistry portion saw progress through improved CVs and spectrophotometry results. The microscopy section was also improved by switching from a CLIC setup to two flat pieces of glass with fine-tuned parallelism and distance. Future work must be done to improve ITO-coated glass gluing procedures to prevent warping. These procedures may involve using different types of glue and tools to position the glass. In addition, the physical trapping of cyt c must be made more efficient and replicable for future research toward developing biosensors using BRCs.

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EVALUATION OF CHINA'S "DOUBLE REDUCTION POLICY" WITH SYNTHETIC CONTROL: ITS SEVERE INFLUENCE ON INDUSTRIAL GROWTH & STOCK MARKET VOLATILITY

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Abstract

Introduced in July 2021, China's "Double Reduction Policy" has a sweeping effect on both public education and the K-12 after-school tutoring sector, where parents and students are being affected nationwide. Yet its economic influences are left to be examined. By comparing China with other "involutionary" Asian countries (where students fiercely compete for grades with each other) using the synthetic control method, we generate a "fake" China to simulate the "if the 'Double Reduction Policy' did not take place, then what could happen" scenario to evaluate its market impacts on the after-school private education sector. The result shows that "Double Reduction Policy" has made private education stocks in China both more depressed and more volatile, nearly impossible to recover in the short term, providing solid evidence to the subtle interconnection between China's policy and the corresponding part of its economy.

Introduction

1.1 Policy Background

In China, the path to higher education and future success is marked by the "Gaokao", a rigorous examination that serves as a critical juncture in students' lives. This "marathon" of academic endurance not only tests students' knowledge and stamina but also highlights the profound disparities in educational access across different regions and social strata. Urban students often benefit from richer educational resources, while their rural counterparts face significant hurdles, stemming from an entrenched social and regional imbalance[1]. Despite government efforts to mitigate these disparities, the high-stakes nature of the Gaokao continues to place immense pressure on students, underscoring the need for a more equitable and holistic education system[2].

Thus, for the purpose of trying to improve such an education system, "Double Reduction Policy" was implemented by the Chinese Government nationwide on July 24th, 2021, aiming to free primary and secondary school students from heavy burdens caused by extracurricular tutoring. The phrase "double reduction" means both reducing the homework burden and the after-school training burden for students at the stage of compulsory education, that is, 9-year minimum education from the beginning of primary school to the end of middle school. The expectation of this policy was to improve the quality of on-campus public education, ensure a fair entrance examination among students, and achieve a transformation to happier family education[3]. However, this also implied that nearly all private tutoring institutions would be banned and expelled from the market.

1.2 Doubts and Questions

The actual effect of this policy is controversial, given that there is no clear evidence of a "reduced" burden on students nor a higher happiness index being discovered in comparison to previous years. Yet from another perspective, we doubted the underlying influence brought by the "Double Reduction Policy" on the nation's economic side. As the market volume of the Chinese education sector is expected to reach CNY 4.09 trillion (aka. $572.51 billion) in 2023, occupying 3.24% of China's total GDP for the same year[4]. Such figures highlight the education sector's pivotal role in fueling economic growth, reflecting its importance not just in societal development but also as a major economic driver within the world's second-largest economy.

To recap, the implementation of China's "Double Reduction Policy" aims to overhaul the education sector by limiting the amount of homework and after school tutoring for students. Through limiting homework loads, restricting night study, and after-school tutoring, the policy aims to achieve a more harmonious and well-rounded educational environment for students. In a symbolic effort to combat commercialization, the government has outlawed the operations of for profit educational entities in exam-based compulsory subjects with a complex structure of tight industrial regulation and improvement of teaching staff. How did this policy affect China's private educational sector? What is the potential association between the implementation of "Double Reduction Policy" and the stock market performance on relevant shares? Why is the stock market a good reflection of economic trends on corresponding industries (even though it is the so-called immature Chinese stock market)? Intrigued by these questions, our research will use the synthetic control method to find out the impact of "Double Reduction Policy" on the Chinese private education sector using stock prices as an instrument with potential confounders being addressed.

1.3 Motivations from Student & Economy's Perspective

Like other Asian countries with rigorous educational selection processes, Chinese kids have also grown up with overwhelming burdens from schoolwork and expectations from parents to enter high-ranking universities. The pressured educational

system is on their shoulder if parents do not have a peaceful attitude toward the extremely competitive surroundings. Thus, as someone who experienced such an education system from childhood, the "Double Reduction Policy" naturally drew our attention and many other students along with their seemingly pushy parents.

While the happiness of students is hard to determine and measure, since no existing public surveys or data can be referred to, its short-term impact on the economy side has been severely concerned. Thus, the intersection between such across-the-board policy and the economic conditions motivates us to think about its impacts on both the economy and livelihoods, as well as any implications for the near future. With the tendency of increasing political instability in mainland China during recent years, the implementation of "Double Reduction Policy" is a typical example of how one piece of policy can change an entire business sector.

During the past two decades, educational institutions have experienced a blowout explosion. Because of China's huge population base, teenagers started to compete fiercely, which has led businesses to target opportunities driven by their parents' demand for high scores. But the introduction of "Double Reduction Policy" is like a heavy rain that extinguished nearly all the business flame of after-school tutoring services. The withdrawal of investors has precipitated challenges in the capital chain within private education sectors, culminating in teacher unemployment and a precipitous decline in stock prices, driving many esteemed companies towards bankruptcy. Among these, New Oriental Education & Technology Group, a cornerstone in China's educational landscape since its inception in 1993 by Yu Minhong, witnessed its stock prices plummet by as much as 50%. This institution has been pivotal in providing a comprehensive array of educational services, including test preparation, language training, and K-12 education, serving millions through its expansive network of physical centers and online platforms. Similarly, TAL Education Group, also known as "Xueersi" (Study and Think), which was founded in 2003 and has been instrumental in offering specialized after-school tutoring across core academic subjects, encountered severe market turbulence. On July 23, it triggered a circuit breaker in the US stock market due to excessive volatility, ultimately seeing a staggering 70.76% drop in its closing stock price. Both New Oriental and TAL Education Group have played critical roles in enhancing educational access and quality in China, symbolizing the significant stature and influential legacy of private educational enterprises in the country's broader educational ecosystem.

1.4 Relevant Literature

Although the "Double Reduction Policy" has only been introduced for a year, a number of researchers have already discussed it from not only an economics perspective but also its overall social influences. In Wu's study[5], China's new regulations on private tutoring have rapidly impacted the education industry. Capital pulled out of the sector overnight, which is another sign of the Chinese government's strong grip on its domestic industry[6]. Wang also agrees with this point of view. Traditional education and training institutions are facing major shocks and "reshuffling". The stock prices of companies in China's education and training industry have continued to fall. Whether it is the reduction of personnel, the optimization of the team, or the adjustment of business, it indicated that China's education and training industry will enter the most painful transition period[7].

At the same time, the off-campus training business dropped sharply by 70- 90%, directly affecting the employment of millions of people, especially women. The employment rate of graduates who aimed for an occupation in education has dropped by 20% comparing to the previous year. Regarding these statistics, Zhang[3] proposed that the implementation of the "Double Reduction Policy" forced those students to actively seek new employment opportunities, gain an in-depth understanding of employment positions that match their

majors, and clarify the demand for talents in each position.

Apart from the economic side, the "Double Reduction Policy" required an overall improvement in the quality of public school education. By improving instructors' teaching ability and homework design, it hopes to reduce the burden on students, meanwhile improving the quality of after-school services. Under a bright expectation, the "Double Reduction Policy" will provide sufficient space for instructors to develop and promote their inner drive to continue learning through institutional design. Such an argument pointed out the significance of the "Double Reduction Policy" for China's fundamental education reform through the parents-school-students structure. Other researchers stated that it will reduce family education expenditures, which is a great benefit to households[6]. By reducing unnecessary training expenditures, the financial pressure on families will be decreased at the same time.

Past research has also shown that the "Double Reduction Policy" has a considerable impact on both the economy and social environments (education in particular). Yet due to the time limitation, after the policy was implemented in July 2021 till now, not much has been done and there is a certain research gap that needs further investigation. Namely, a plunge in stock prices and institutional failures due to the implementation of the "Double Reduction Policy" (we'll see why this is the case shortly) are of interesting topics that deserve more rigorous analysis and meaningful interpretations.

Methodology and Framework

2.1 Robustness: Fundamentals of Chinese Stock Market

Though known for its immaturity, some of the key characteristics of China's stock market are similar to those of the developed economies. It is purely order driven, centralized, and informative. Admittedly, China has a segregated capital market due to its "closed" capital account policy, meaning that money, including investments, cannot be freely moved in or out of the country. This has led to a low correlation between China's stock market and the foreign ones. Moreover, famous Chinese economist, Wu Jinglian, and others have doubted that the Chinese stock market is acting like a casino manipulated by speculators and the central government, which has been proved wrong later in 2015[5].

However, studies have shown that the trend of stock price informativeness is highly correlated with the corporate investment efficiency, indicating information regarding company fundamentals and future profitability have been efficiently incorporated into stock prices[8]. Similarly, Chinese investors would price risk, fundamentals and other stock traits the same way as investors from large economies. From which, we conclude that China's stock market is effective in terms of its cross-sectional return pattern within market and industry, despite the fact that it is relatively immature and volatile with a greater idiosyncratic risk compared to other developed countries like the US. Therefore, the stock market in China should not be treated as an outlier due to its reflective functionality, though we will take volatility and the hit of COVID-19 into consideration.

2.2 Association between Stock Prices and Industry Performance

To use stock price as an indicator of industrial performance among private education companies, we need to first understand the essentials of stock, as well as its relationship with the economy. The existence of a well-functioning stock market both boosts the economy and indicates the relevant industrial growth, which plays an important role in macroeconomic fundamentals. By allowing fund transactions from people who possess financial surplus to those companies who need the resources for future uses, the way stock market functions have increased productivity with economic efficiency for companies, meanwhile providing asset liquidity and valuable information for the

the general public[9]. Apart from the advantages that the stock market brings, there exists a bi-directional Granger causal relationship be tween stock market returns and industry returns among many Asia countries including China, in which they are interdependent to each other[10]. Their study showed that the stock prices are closely correlated to the performance of an economic system. Structural breakdown in the stock market introduced by external factors or policies should not be neglected in this way and will provide potential insights for movements in macroeconomics.

Therefore, due to the characteristics of transparency and strong correlation to industrial performance that the stock market has, we decide to use the stock price movements of private educational service companies as a primary response variable to analyze the effect of "Double Reduction Policy" on the country's economic side.

2.3 Control Units: Other Asian Countries that are Educationally Competitive

Our investigation into the educational policy impacts within China leverages the Synthetic Control Method. This methodological approach is pivotal for us to conduct a comparative analysis when random assignment is not feasible. We synthesized a control group from Japan, India, and South Korea, chosen for their analogous contributions to the Asia K-12 after-school training (AST) sector and shared educational challenges with China[11]. Students from those countries essentially have the same needs as Chinese students to compete for a high-quality college entrance opportunity under the exam-oriented educational systems due to "involution". Thus, even without a large amount of revenue generated, South Korea is yet being included as a control unit considering its highly "involutionary" nature.

Involution is a term that was first taken by the Chinese internet in 2020 that describes the intensive exam-based competition faced by students who strived to enter a better university to further compete for scarce jobs, given that unemployment has become a a significant yet common problem in China[12]. The emergence and persistence of involution reflect the increasing eco nomic scarcity of industrialized East Asian countries, where compounded aging populations has caused stagnation and further led to other social problems[13]. It soon explains the competitive educational phenomenon of several Asian countries that face similar economic issues as China. In this case, we believe that it is a nation's operational structure that leads to the heavy burdens to young students, not the after-school training programs themselves. Through SCM, our study aims to discern the intersection of educational policy, market economics, and investor behavior within the competitive educational sectors of East Asia.

2.4 Covariates: Factors that Lead to Stock Price Fluctuation

Given that our primary response variable is the stock price movement of private educational companies from the Asia K-12 after school training sector, the selected covariates would therefore be factors that influence stock prices from both the market level that accounts for macroeconomic conditions and the idiosyncratic level that variates regarding to each company. Under the discipline of behavioral economics, humans have a natural tendency to be overconfident thus overemphasize the data, react with greater pain in bear market due a sense of loss aversion, or persist in a false understanding because of inertia and a consideration towards sunk cost. In this case, we are conscious of the fact that market sentiment factors should be added as covariates for synthetic control yet cannot be quantified with data.

In terms of the idiosyncratic level factors, we will include earnings per shares (EPS) that represent earning bases and price-to-earnings (P/E) ratio for valuation multiples as covariates in this study. Because both indexes are essential for determining a company's fundamental value, hence have potential influences on the company's stock price. To be more specific, EPS is calculated as a firms' profits divided by the number of outstanding shares, indicating its current

profitability. While the P/E ratio is calculated as the current share prices divided by EPS, representing the discounted present value for a company's future earnings expectations by considering both the growth rate of earning bases and the discounted rate determined by the interest rate[14].

Market level factors are correlated with the idiosyncratic level factors in an intertwined manner, which will further affect the stock price movements. Monthly inflation and quarterly GDP growth rate are the two major covariates that we have considered in the market level. Acting as the mirror of interest rate, inflation rate will trigger a higher discount rate hence affecting the P/E ratio. Similarly, a fast pace of economic growth (aka. an outward shift in production curve, thus a higher gross domestic product) would indirectly contribute to a company's earnings growth. Both indexes are worth considering as potential confounders for private educational stocks that take place in different countries.

Empirical Analysis

3.1 Data and Variables

Our analysis leverages data from CEIC[15], a leading repository of global eco nomic indicators, for insights on inflation rates and quarterly GDP figures, complemented by stock price movements from Yahoo Finance[16], a primary source for real-time market data. These sources were chosen for their comprehensive coverage and reliability, enabling a detailed exploration of economic trends and market responses.

We implemented the synthetic control method to evaluate the effect of policy intervention by systematically selecting comparison groups and comparing them to our treatment group (which are representative private education firms from China, such as New Oriental Education, TAL Education, China Online Education Group, etc.) after accounting for any covariates listed above. Countries that served as control units have the same traits as China based on their similar pressure for private K-12 tutor sessions. In this case, we have chosen Asian countries with similar competitiveness in the field of K-12 private educational sector by using a weighted combination of companies such as Benesse Holdings from Japan, Educom Solutions from India, Woogjin ThinkBig from South Korea, etc.

Each country has its associated monthly data within the time period of 2018- 2022 (where the policy was implemented in July 2021) to illustrate the trend of growth in stock price, GDP, and inflation. Among which, the average stock prices in different countries are one of the most obvious indicators of the impact of the "Double Reduction Policy".

Note that the EPS and P/E ratios for each company are what we would like to include as covariates, however, they were mostly collected yearly and quarterly. Since the "Double Reduction Policy" has only been implemented for one year, it is hard to collect these data and reflect the effectiveness of this policy from these two aspects.

3.2 Modeling Strategy

As introduced above, the treated unit is China, and our outcome of interest is stock

CHINA	Mean	SD	Min	Max
MoM Inflation	102.0817	1.215785	99.5	105.4
QoQ GDP Growth	1.020746	.120966	.7483713	1.191881
Avg. Stock Price	53.39751	35.26374	6.824	121.92
Stock Index	92.77918	61.27141	11.85683	211.8383
Treatment Factor	.2833333	.4544196	0	1
INDIA	**Mean**	**SD**	**Min**	**Max**
MoM Inflation	153.9333	12.52325	136.4	176.7
QoQ GDP Growth	1.016244	.1022943	.7224654	1.238853
Avg. Stock Price	2.974167	1.382962	.95	8.25
Stock Index	36.05051	16.76318	11.51515	100
Treatment Factor	0	0	0	0
JAPAN	**Mean**	**SD**	**Min**	**Max**
MoM Inflation	100.3133	1.167856	99.1	104.1
QoQ GDP Growth	.9912302	.0549787	.8959641	1.108556
Avg. Stock Price	24.76633	6.030067	14.42	37.07
Stock Index	70.29899	17.11628	40.93102	105.2228
Treatment Factor	0	0	0	0
SOUTH KOREA	**Mean**	**SD**	**Min**	**Max**
MoM Inflation	101.753	3.347034	98.11	109.26
QoQ GDP Growth	.9986527	.0485596	.9064762	1.089084
Avg. Stock Price	26752.39	11665.04	9009.589	53050
Stock Index	256.4777	111.8338	86.37579	508.5954
Treatment Factor	0	0	0	0
TOTAL	**Mean**	**SD**	**Min**	**Max**
MoM Inflation	114.5203	23.71895	98.11	176.7
QoQ GDP Growth	1.006718	.0875927	.7224654	1.238853
Avg. Stock Price	6708.382	12964.3	.95	53050
Stock Index	113.9016	106.6302	11.51515	508.5954
Treatment Factor	.0708333	.2570824	0	1

Table 1. Summary statistics. N=240.

Date	Country	Company	Close Price	Inflation	QoQ GDP	GDP Growth
01/01/2018	South Korea	Woongjin ThinkBig	6461.38	98.11	419430.39	-2.52
02/01/2018	South Korea	Woongjin ThinkBig	6139.18	98.86	419430.39	-2.52
03/01/2018	South Korea	Woongjin ThinkBig	6078.22	98.75	419430.39	-2.52
Date	**Country**	**Company**	**Close Price**	**Inflation**	**QoQ GDP**	**GDP Growth**
01/01/2018	Japan	Benesse Holdings Inc	35.23	99.5	1282749	-0.127695
02/01/2018	Japan	Benesse Holdings Inc	37.07	99.5	1282749	-0.127695
03/01/2018	Japan	Benesse Holdings Inc	35.86	99.5	1282749	-0.127695
Date	**Country**	**Company**	**Close Price**	**Inflation**	**QoQ GDP**	**GDP Growth**
01/01/2018	China	China Online Education	48	101.5	3180162.13	-11.948982
02/01/2018	China	China Online Education	39.43	102.9	3180162.13	-11.948982
03/01/2018	China	China Online Education	38.88	102.1	3180162.13	-11.948982
Date	**Country**	**Company**	**Close Price**	**Inflation**	**QoQ GDP**	**GDP Growth**
01/01/2018	India	Educomp Solutions	8.25	136.9	712200.09	5.843724
02/01/2018	India	Educomp Solutions	6.2	136.4	712200.09	5.843724
03/01/2018	India	Educomp Solutions	6.2	136.5	712200.09	5.843724

Table 2. Sample Stock Data with Quarterly GDP Growth

price fluctuations for institutes that offer private K-12 tutor sessions after the new policy launched in July 2021. The covariates are therefore monthly inflation, and quarterly GDP growth rate. Some potential controls are Japan, India, and South Korea.

After settling down all the variables and data, we have implemented synthetic control to create the synthetic (fake) China as an average of potentially controlled countries to reproduce a counterfactual situation. The method of synthetic control allows us to successfully create the "if 'Double Reduction Policy' did not take place, then what would happen?" scenario. Thus, we deem that synthetic control would be most suitable for analyzing such nationwide policy effect by com paring with other countries holding similar educational dilemmas and economic structures yet did not have corresponding policies implemented. Therefore, symbolically speaking, *Di(1)* refers to China that implemented "Double Reduction" Education Policy, while *Di(0)* are other Asian countries where K 12 after-school training are popular but did not implement the "Double Reduction Policy".

Given this framework, we formalize our model as follows:

$$Y_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 I_{it} + \beta_3 G_{it} + \mu_i + \gamma_t + \epsilon_{it}$$

where:

- Y_{it} denotes the average stock price growth of of private education companies in country *i*
- T_{it} is an indicator variable for the treatment effect, equal to 1 if the "Double Reduction Policy" is in effect for country *i* at time *t*, and 0 otherwise.
- I_{it} represents the monthly inflation rate in country *i* at time *t*.
- G_{it} captures the quarterly GDP growth rate in country *i* at time *t*, providing a comprehensive understanding of the economic landscape.
- μ_i captures country-specific fixed effects.
- γ_t represents time-specific fixed effects.
- ε_{it} is the error term.

One advantage brought by the synthetic control method is that it offsets the effect of COVID-19, as COVID-19 has hit every country at nearly the same level. No one is exempted, including countries from our comparison group. Yet we are aware of the cultural and political differences between China and other Asian countries that might affect stock price volatility of private education stocks. Thus, we have included market level covariates such as inflation and GDP growth to try to account for such potential biases.

3.3 Outcome Results

Using the time series data, synthetic control is taken as our representation of "what if the policy has never been introduced in China" to know whether the outcome of the "Double Reduction Policy" has deviated from such counterfactual benchmark.

The figure below plots the trajectories of the average stock price movement of China's stock market and the average stock price

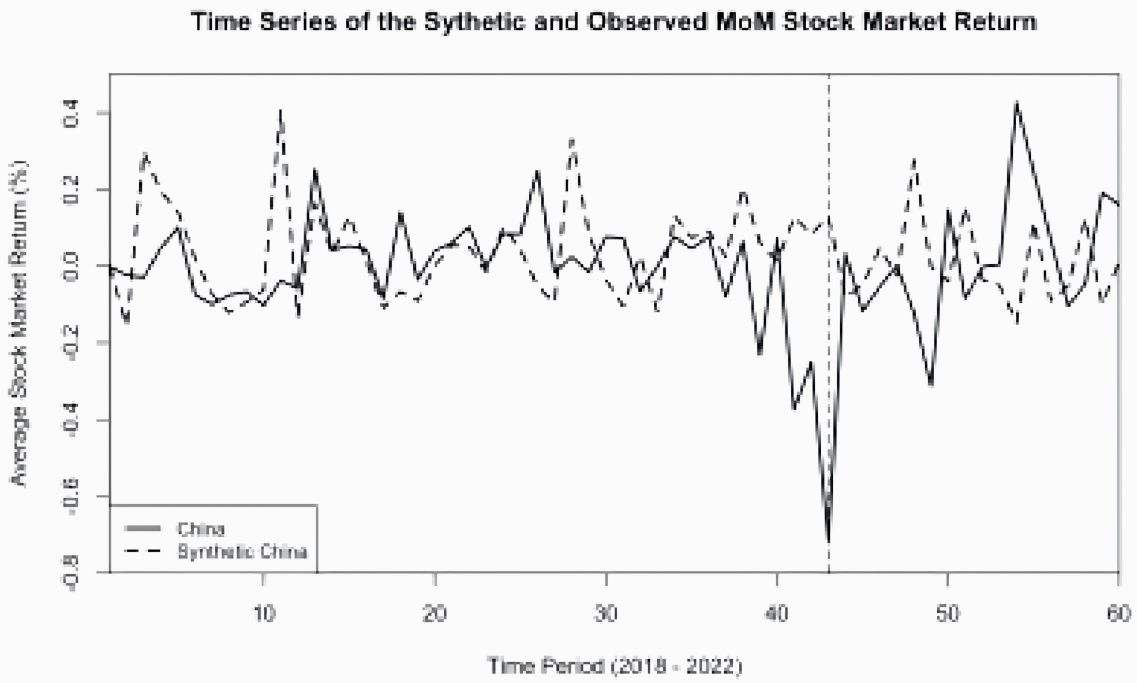

Fig. 1. Time series graph of synthetic and observed outcomes (stock returns).

movement of synthetic China's stock market in the private education sector over the period from January 2018 to December 2022. The divergence in February 2021, as observed from the graph, is not the true treatment effect. Although the "Double Reduction Policy" was announced in July, many stockholders began to liquidate their positions due to the early leak of internal information. That led to the steeply falling trajectory in February. In the treatment period, when the "Double Reduction Policy" was introduced in July, the gap started getting wider with a serious plunge in the stock price. At the same time, synthetic China still behaved quite steadily. After the policy had been announced for a while, the descending trend has been stabilized, from -71.65% to nearly 0%. In the following 17 months, the trend between actual movement and synthetic movement was relatively constant, yet still more volatile than the synthetic China. Note that an obvious rise in August is due to the stock indicator we used, which measures the price fluctuation of this month compared with the previous month. In addition, the stock price has fallen by 90% and there is no room for further decline, hence the average stock movement was forced to become constant after the policy was implemented. Figure 2 and Figure 4 used the weighted stock index as an indicator instead of the stock market return, which yield a more clear result of how China with the policy implemented has deviated from the synthetic China generated by all other controlled countries. This piece of evidence further indicated that the impact of "Double Reduction Policy" on education stock markets was an absolute disaster. In Figure 3, we evaluate the validity of results by conducting a placebo test that involves iteratively applying the synthetic control method to each of the controlled countries. Thus, control groups here are acting as a placebo. As observed, the gap estimates between China and other controlled countries are extremely large, indicating that our synthetic control analysis has proven to have significant effects on the implementation of "Double Reduction Policy".

Limitation and Potential Improvement

The major limitations of this research, as mentioned before, are barriers to accessing data relevant to idiosyncratic factors of stocks and the pains for manually collecting them, which has further led to a relatively small sample size. Also, while conducting data

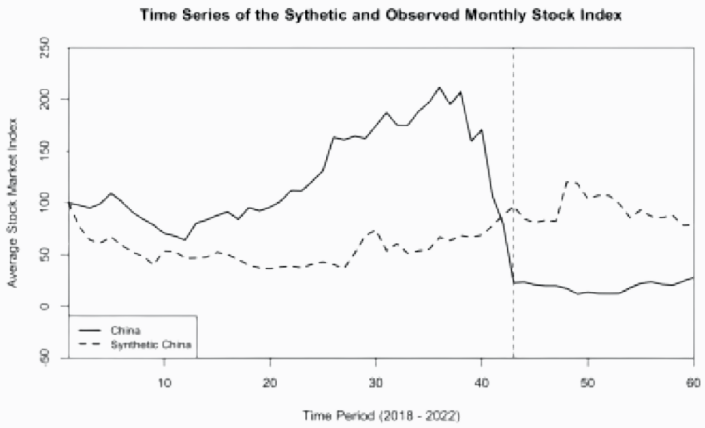

Fig. 2. Time series graph of synthetic and observed outcomes (stock index)

Metric Estimate	S.E.	CI Lower	CI Upper	p-value
0.07027	0.02859	0.01424	0.1263	0.01397

Table 3. Average treatment effect on the treated.

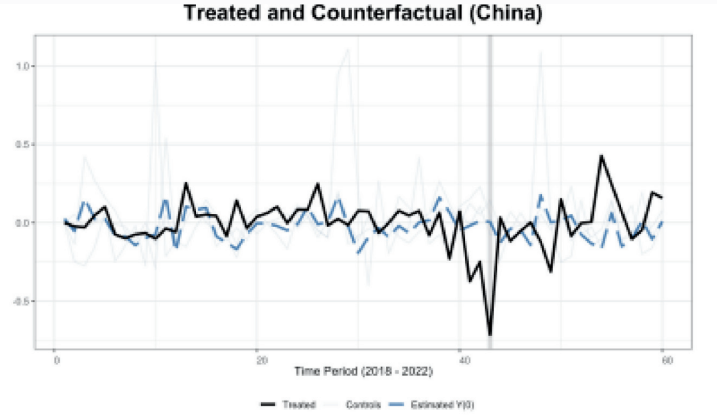

Fig. 3. Validity test of the time series result (stock return)

	Covariate Beta	S.E.	CI Lower	CI Upper
MoM Inflation	-0.0001547	0.002433	-0.004923	0.004614
GDP Growth	-0.4443484	0.589785	-1.600307	0.711610

Table 4. Coefficients for the covariates.

Fig. 4. Validity test of the time series result (stock index)

collection, we realized that China's information is not as transparent as it should be, blocking us from broader data availability. Second, such a short period of policy introduction makes it hard to quantify the potential influence and uncertainty brought by COVID-19 and whether China has been affected by it more severely compared to our control units. Third, market sentiments like panics during the mass selloff are acting as unobservable in this study, which is likely impossible to eliminate or control when it comes to the movements of stock markets. Fourth, the profit models of those private education companies that we selected might also be different and worth proper examination. Some of the potential improvements are, first, to broaden our dataset and to include more private educational stocks for each control unit. Second, to analyze the immediate impact of "Double Reduction Policy" on other economic factors like unemployment rate, which we are having a hard time finding reliable data. Third, to examine the long-term economic effect of "Double Reduction Policy" as the post period prolonged.

Conclusion

Above all the information, evidence, and data we collected and the synthetic control methods we used for analysis, it is significant that the implementation of China's "Double Reduction Policy" on July 24th, 2021, has brought sudden shocks to the corresponding private educational sectors, especially those specialized in K-12 after school training. If the policy has not been implemented, then we are expecting a gradual increase in the Chinese education stock index within estimated China (after combined the stock performance of all the controlled countries) from 100 to above 200, instead of falling to as low as 11.85. The scale of the off-campus training market is about 2 trillion yuan among entire Chinese education sector of 4.09 trillion yuan, which contributes about 2% of the GDP. It is very impressive for a giant economic entity. Our result also means that the market proportion in this industry will be greatly reduced. We are thrilled to learn more about the impacts of "Double Reduction Policy" and dig deeper for perfection in the near future. With the "Double Reduction Policy", both researchers and general public have witnessed a clear trajectory of the negative influence brought by government policies to the economy. We hope that this research could not only serve as a vivid example of how policies in China can severely affect relevant industry in an unexpected way, but also shed light on the importance of seeking a balance point between social developments and economic impacts through the process of policy-making.

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ANALYZING ATTITUDE SHIFTS INFLUENCED BY NATURAL NOISE VERSUS ANTHROPOGENIC NOISE OF MIDDLE SCHOOL STUDENTS

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Abstract

The present study experimentally investigates the effects of short-term exposure to natural noise and anthropogenic noise on the attitude of middle school art students in Southeastern Virginia. Six middle school art classes were exposed to a noise sample, three of which listened to natural noise and the other three anthropogenic noise. Data was collected as a behavioral survey, asking students to draw how they felt twice, once before the noise sample was played and again afterwards, while simultaneously answering an additional survey question. The drawings were then analyzed by lines, colors, light, and the students' survey answers. This measure quantified the qualitative drawing to determine the attitude of students at the given moment. For many students exposed to natural noise, their attitude rating increased, leading to a more positive attitude after the noise exposure. On the other hand, most students exposed to anthropogenic noise had an opposite reaction, with decreased attitude ratings. This study shows that short-term noise exposure has an influence on attitude. Given the proven possibility of emotional effects to noise pollution, further research needs to be done regarding long term noise exposure and effects on emotional health.

Introduction

When explaining the state of the planet, National Geographic asserts, "Earth's seen 20,000 years of change in [the last] 170 [years]."[13] Since the Industrial Revolution of the 1850s, the environmental well-being of the Earth has plummeted. The increased use of harmful chemicals and non-eco-friendly practices has led to a multitude of environmental problems, including noise pollution, an often-underestimated problem, which impacts millions of organisms, including humans.[7] According to the United States 1990 Clean Air Act, noise is defined as "unwanted or disturbing sound" with sound being a vibration transmitted through a medium, in this case, air.[4] Once sounds conflict with everyday activities, communicating, or an individual's quality of life, they are considered to be unwanted. In the scientific community, there are two types of noise: natural and anthropogenic. Natural noises are sounds made by non- humans, either biotic creatures or abiotic factors. Anthropogenic, on the other hand, refers to an act of pollution originating from humans, in this case noise.

The research question for this study is as follows: *How do middle school art students' attitudes shift when exposed to either natural noise or anthropogenic noise in southeastern Virginia?*

To ensure the study follows its focus, three main goals were set. The first goal is to see if there is a change in emotion after hearing different noises. There have been many studies proving that there exists a human emotional connection to sound, but this study aims to see if emotions change as a result of different noises. Emotions are powerful tools that can dictate the way people think and feel, which is why finding an emotional reaction is important.[19]

Previous research has shown that natural and human-made noises are constantly conflicting variables as they are most often present through a person's day-to-day life.[3] For this reason, the second goal of this study looks at the outcomes of exposure to both both natural and human-made noises. If a difference in emotion is demonstrated between the two variables after the research is conducted, people may better understand how to build their surroundings in the context of their emotional well-being. The last goal of this study is to determine if this emotional reaction is a result of noise pollution. Sounds connect to feelings, but these connections may not necessarily be an outcome of noise pollution directly. Additionally, several otorhinolaryngologists, doctors of the ears, nose, and throat, explain that even people who understand the physical harm of noise pollution do not avoid exposure to it.[5] Meaning, if an emotional effect of noise is proven, people may be more inclined towards limiting exposure.

Hypothesis

The hypothesis is that if natural noises are played in front of the participants, then they will reflect an increased attitude rating and if human-made noises are played, then they will reflect a decreased attitude rating. As mentioned before, scientists have found an emotional link between sound and emotions, supporting the basis behind the creation of this hypothesis.

Literature Review

"Hearing is primal. You don't have ear lids. There is no way to turn it off. You hear everything around you all day, all the time," clarifies the founder of The Sound Agency, a firm that works on audio advertising.[12] Sound is constantly present, which is why excessive exposure poses a threat to people.[7]

Physical Effects

Noise and health are directly related. The EPA found that noise pollution causes "stress related illnesses, high blood pressure, speech interference, hearing loss, sleep disruption, and lost productivity."[4] Of these symptoms, the most prominent is Noise Induced Hearing Loss (NIHL), which can have temporary or permanent effects. To exhibit these

symptoms, noise exposure has to either be initial and loud or present over a long period of time. Sound is measured in dBA, decibels relative to the human ear. The current sound standards within the workplace in the US are limited to no more than 90 dBA for more than 8 hours, 95 dBA for 4 hours, and 100 dBA for 2 hours. Any constant exposure to 115 dBA violates this code. As for instant sound, the sound cannot exceed 140 dBA.[1] For context, a jet engine at 30 miles an hour is 150 dB.[11] Although these standards are put in place, noise still manages to exceed these levels, causing damage to people's physical health.

GeoJournal, a peer-reviewed international academic journal focused on geography, found that levels of noise pollution are higher in urban areas.[8] As more people move to larger cities for work, the higher concentration of people brings more noise. Since cities are continuously increasing in size, noise pollution is growing as well.

Emotional Effects

A study done by the University of Pennsylvania found that there is a link between sounds and emotions.[14] Specifically, when people hear certain sounds, it prompts their brains to release primary signaling chemicals, making the subject feel a certain way. With this information, it logically follows that noise pollution could have emotional consequences.

Emotions dictate many aspects of people's lives. Besides affecting people personally, they also contribute outside factors. Gerben Van Kleef, a social psychology professor at the University of Amsterdam, found that emotions have the ability to impact people's social interactions.[18] His study suggested that positive emotions lead to positive communication and better relationships with others, and the opposite with negative emotions. In his study, he also found that outside factors can influence these emotions, including noise.

Additionally, the Visual Arts Research Journal conducted a study that found children were able to express their emotions through art.[10] It was also shown that as children grow older, they can better understand and describe their emotions through art, leading their drawings to be more sophisticated and detailed. Through the characteristics of art, scientists can use certain criteria to determine the emotion expressed in an art piece.

Historic Challenges

Noise is an aspect of air pollution, but it is often ignored in efforts to combat air pollution. In 1970, the United States passed a federal law named the Clean Air Act.[4] This law had six titles, each corresponding to a different aspect of air pollution that would be addressed by the country's Environmental Protection Agency (EPA). Section IV of the Clean Air Act, the Noise Pollution and Abatement Act of 1970, created the Office of Noise Abatement and Control (ONAC) within the EPA to measure the effects of growing noise in urban areas on its residents.[15] President Ronald Regan did not believe that noise posed a threat to people and as a result cut off financing to ONAC. Although the EPA still had the authority to combat noise pollution under the Clean Air Act, there was no money to fund the initiatives. Since noise is not visible, people often feel that there are no direct negative impacts from it— however, the reality directly contradicts this assumption. These attitudes caused limited noise research in the United States at that time, creating a gap in current noise knowledge. In 1991, the World Health Organization declared "noise must be recognized as a major threat to human well-being."[16] In the meantime, in 2007 the Southern Medical Journal stated that noise pollution had only worsened.[7] A problem with such intensity needs more attention brought to it. Noise pollution has become a greater interest in modern scientific literature, but more research is still imperative.

Gap

The gap in the body of knowledge for this study is the emotional effects of noise pollution. Many studies have been

conducted on the physical impacts of noise pollution, with Noise Induced Hearing Loss (NIHL) being the most severe side effect. Despite this, there is very little if any proof that noise pollution is directly related to emotional health. As a result, this research aims to add to the body of knowledge and discover whether or not there is a correlation between noise exposure and a shift in attitude. This study is different than those in the past as it tests both natural and human made noises. Additionally, the participants for this study are children, not adults, which is not common in previous literature for this subject. Therefore, a wider range of information regarding emotions and noise will be added to the body of knowledge through this study.

Method

Participants

For this study, it is imperative to include an age group that has the ability to express their emotions through drawings. Children have this trait, but an age group too young would pose a problem, for they must understand the task at hand. Middle school makes for the ideal age group because they match the criteria listed above. Specifically, middle school art students were observed because art students would be better versed to express their attitude through drawings.

As for the schools, every public middle school within a certain city in southeastern Virginia was contacted for permission to conduct this study. Since the number of schools that would approve the trial was unclear, it was illogical to randomly sample the schools. However, every accessible school was contacted, and every school which approved the trial was assessed. Therefore, no personal bias was attributed to selecting the schools. In the end, six classrooms were assessed, classes A, B, and C were natural noise sampled, while classes D, E, and F were anthropogenic noise sampled. The school's administration and art teachers gave permission to enter every classroom. No parental permission was necessary since no names or identifying features were given to me nor released in this paper, and all students remained anonymous.

Variables

Several constants had to be put in place for this study. Drawing materials remained constant; all students had access to a wide variety of colored pencils, crayons, markers, and pastels. Students were allotted five minutes for drawing both before and after hearing the chosen noise, with a timer used in order to ensure that the lengths remained the same. The same paper and survey questions were distributed to all students.

In order to keep the sample as legitimate as possible, the first task students had was to draw how they felt, the "neutral drawing." This control data was conducted before any noise exposure. Thus, ensuring a proper reference with which to compare their second drawings. The independent variable was the noise sample. Although there was only one natural noise sample recording and one anthropogenic noise sample recording, the samples were rotated between the classes to garner different results. Three classes listened to the natural noise, while 9 another three listened to the anthropogenic noise sample.

Lastly, the dependent variable was the drawing students created after listening to the noise sample. Students were to draw anything they wanted, as long as it was school appropriate. This allowed the students to express their current attitude with a wide range of creativity. Mood is the way somebody feels over a period of time, while attitude is the way someone feels at an exact moment or situation. For the purpose and resources available in this study, attitude will be measured.

Materials

For this study, a variety of materials were needed. Each class was provided with sheets of paper, survey sheets, and noise samples. I created the 20-second noise samples by recording in different areas located in Southeastern Virginia. The natural noise

sample had streams, rain, and birds chirping from a nearby preserve. The anthropogenic noise sample included traffic, people moving, and airplane jet engines found in a nearby downtown city area. A speaker was used to play the samples out loud for the classes. The only items not provided were the art supplies. Before entering each classroom, teachers were asked if they could provide a wide range of colored pencils, crayons, markers, and pastels. Every teacher confirmed that they could; therefore, it was unnecessary to bring any.

Collection Plan

To ensure validity, the same method was implemented in every classroom. Each classroom was entered at the appointed time given by the teacher followed by a brief introduction, stating my name and the topic of the study. To ensure that the samples were genuine and not preconceived, the students were not informed of what would be specifically done with their drawings.

Next, each student was handed a blank sheet of paper by both me and the teacher and asked to write the letter "N" in the top left corner. The "N" stands for neutral; this was done to tell the difference between the neutral and post-noise drawings. Then, the students drew how they felt at that present moment (see Figure 1). Five minutes was allotted to drawing time as a small survey sheet was distributed as depicted in Figure 2. The reason for the survey sheet was to prevent inaccurate response bias. By connecting the way students drew their feelings to what they circled on the sheet, it created a more accurate way to attribute an attitude to a drawing.

After that, a noise sample was played. Classes rotated between the natural noise sample and the anthropogenic noise sample. A total of six middle school classes were involved in the study, so each sample was played three times. Only one sample was played for each classroom to prevent a biased result. Before the trial kept going, students were asked if they had fully heard the noise sample, if not, it was replayed.

Following the noise sample, students flipped over the sheet on which they drew the first drawing. If students used markers that bled through the first sheet, a second sheet of paper was provided. On this second sheet, they drew the way they felt again. Every time, it was emphasized to draw the way they felt after listening to the sample, not to draw what was heard. As they drew, a second survey sheet was passed around (see Figure 3). The purpose of the second survey sheet was the same as the first, to prevent personal assumptions when analyzing the drawings. Once all was done, students lined up and stapled their papers and survey questions together for collection.

Collection Explanation

The explicit method for this research is a behavioral survey. A behavioral survey is a type of survey that asks people about their actions or behaviors that affect their physical, emotional, or mental well-being. Since this study looks at how certain noises make the students feel it fits the criteria for behavior. It is the most effective method for this research since what is being tested is a change in attitude after listening to certain noises. With the resources that are available, this is the most effective way to answer the proposed question.

Fig. 1. Trial in progress. Students from Class A create their neutral drawings. Direct approval from the teacher was obtained for the use of this image since no faces are revealed.

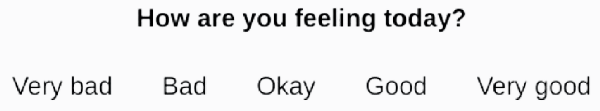

Fig. 2. Survey question 1.

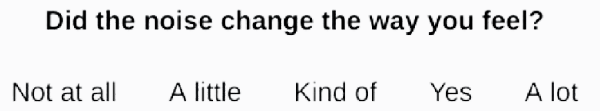

Fig. 3. Survey question 2.

Analysis Plan

Amiria Gale's "How to Analyze an Artwork: A Step-by-Step Guide" to analyze student drawings was used for data analysis.[6] Gale is an artist, an art & design teacher, a curriculum co-coordinator in Art & Design, and an author. Her work is specific to contemporary art, and she has been featured in many of New Zealand's art galleries; she now focuses on helping students that are studying art, particularly through her book "Outstanding High School Sketchbooks." In her guide, she dives into the specifics of how art techniques such as lines, light, and color express the creator's emotions.

Lines

In her guide, lines are the first characteristic that is relevant to this study. When analyzing a drawing, it is important to look at the lines that are most prominent within the drawing, referred to as dominant lines. Lines will be organized into three categories: straight lines, chaotic lines, and curving/organic lines. Straight lines represent order and minimize emotion, showing neutrality. Chaotic lines suggest panic and agitation, showing a negative emotion. Curving/organic lines show peacefulness and happiness, demonstrating a positive emotion.[6]

Light

Light is depicted in two ways, in colors or in symbols. In Gale's guide, she emphasizes that light represents hope and positive emotions, while darkness and shadows show the opposite like desperation and negative emotions. Another way to find light is in objects that represent light. A light bulb and a flashlight are two different ways to show positive light. On the other hand, a dim-lit candle and shadows show negative light or darkness.

Color

There are many attributes to color, but for the purposes of this study, color temperatures and intensity were specifically analyzed. These two aspects will be combined, according to Gale's guide, to represent emotion. Gale states that bright, warm colors, such as shades of yellow, orange, and red, show happiness and positive emotions in a drawing, but can also represent anger. Opposingly, dull, cool colors, including shades of blue, green, and purple, show sadness and negative emotions in a drawing, but they can also represent peacefulness. To avoid the confusion of happiness versus anger and sadness versus calmness, the connotation derived from the previously listed characteristics will be considered to interpret the drawing.

Analysis Limitations

"Art can provide a very natural and safe way for children to express themselves," asserts Innovative Resources, an organization working to provide therapeutic resources for children.[9] For this reason, it is important to use art when attempting to understand the emotional responses from listening to noise. Although there is a reputed art analysis guide being used to analyze the attitude expressed in the students' drawings, there are still limitations, the biggest being myself. I am not an art expert; my background is in the environmental science field. I am not able to analyze art the way an expert can, even with the use of a guide created by an expert. Another limitation is that I am analyzing the artwork alone. With this, I am the only one to form a rationale of what the attitude expressed is. I attempted to overcome this limitation by having the students answer a survey question aligned with their drawing, but this does not address the entire bias.

Results

Quantifying Data

The initial data is qualitative, non-numerical, consisting of analyzing students' neutral and post-noise drawings. To properly analyze the data, the data were converted to quantitative data, numerical, using the drawing analysis techniques mentioned earlier. Demonstrated in Table 1 is how the drawings were quantified. An attitude was attributed to the drawing by considering the connotations of all three drawing techniques and the answer to the accompanying survey question. Examples of specific drawing analysis can be found in Appendix A.

Numerical Score	Lines	Light	Color
Positive (1)	Curving/ Organic	Bright	Warm/ Intense
Neutral (0)	Straight	None	None
Negative (-1)	Chaotic	Dark	Cool/Dull

Table 1. Quantitative Drawing Analysis. The quantifiable measure for the qualitative aspects of drawings.

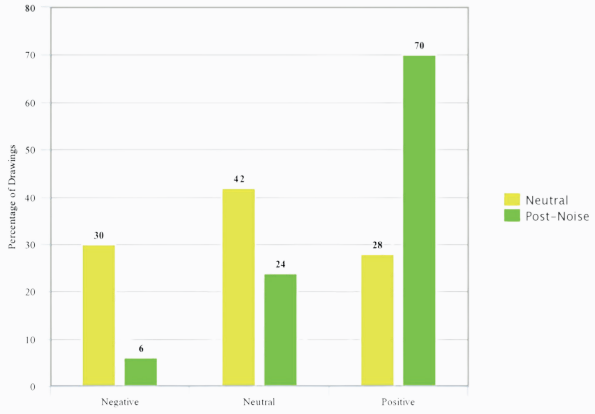

Fig. 4. Attitude Reflected in Neutral vs. Post-Noise Drawings for Natural Noise Sampled Classes

Analyzing Results

Using the quantified data, it is possible to graph the attitudes depicted in the drawings. This also allows the separation of neutral and post-noise data, to test if a correlation is present. Additionally, an accurate way to compare the data collected from natural noises to anthropogenic noises is given through graphs. Since not all classes had the same number of students, the results are analyzed by percentages. Also, it is essential to mention that a total of 16 drawings were disregarded during the analysis process due to an inaccurate following of the procedure.

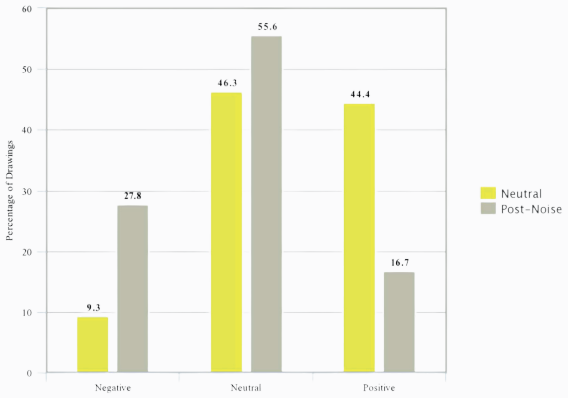

Fig. 5. Attitude Reflected in Neutral vs. Post-Noise Drawings for Anthropogenic Noise Sampled Classes

Discussion

Answering the Hypothesis

As seen through the results, the hypothesis was supported for both the natural noises and anthropogenic noises. This is evident in Figure 4 where the percentage of positive attitudes increased by 42.0% after listening to the natural noise sample. Additionally, the negative attitudes were reduced by 24.0% and the neutral attitudes reduced by 18.0%. The results suggest an increase in positive attitudes after hearing natural noises. More visualizations of natural noise data can be found in Appendix B.

The results also showed that the hypothesis was supported for anthropogenic noises. This is shown in Figure 5 where the percentage of negative attitudes increases by 18.5%. Neutral attitudes also increased by 9%. Although negative attitudes were not the most prominent emotion, it is still evident that there was an increase in negative leaning attitudes after listening to the human-made noise sample. Positive attitudes decreased by

27.7%, leading to the increase in neutral and negative attitudes. This shows that although the emotional link between natural noises and the students' emotions was not as strong as between anthropogenic noises and the students' feelings, it was still clearly present. The attitudes reflected a decreased attitude rating, which supports the hypothesis. More visualizations of natural noise data can be found in Appendix C.

Implications

The data from this research suggests that there is a negative emotional influence due to anthropogenic noise. Therefore, it is possible to suggest that long-term exposure to unwanted noise, such as noise pollution, can be harmful to one's emotional health. The emotional effects of noise pollution have been addressed in this study, but a causational relationship between noise pollution and emotions cannot be assumed from this study alone. This study only strongly supports the idea that there is a connection between the two.

Reaching the Research Goals

Before the trials started, three research goals were established. The first was to assess whether there was or was not an emotional change from different noises. The results successfully proved the possibility that emotions change after listening to certain noises. This is seen in the increase in positive emotions after the students listened to natural noises, and the opposite happening with anthropogenic noises.

There was a clear and present difference in emotional response between natural noises versus human-made. The results demonstrate that there is a difference in the emotional impact of natural noises compared to anthropogenic noises. This is seen in the opposing trends in data, portraying opposite attitude shifts.

Lastly, it has been seen possible that there is an emotional connection between different types of noises and emotions. Specifically, positive effects from natural noises and negative effects from anthropogenic noises. This does not prove that this is the ultimate effect of noise pollution, but it does suggest it is a possible factor. If students were able to reflect such drastic results after being exposed for twenty seconds, long-term and even lifetime exposure may show much more drastic effects.

Limitations

Location: Location is one of the primary limitations. With a limited pool of resources available, only middle school students in public schools in a suburban area in southeastern Virginia were able to be surveyed. People living in the suburbs may react differently to noises than someone living in rural areas or in urban areas. This is because someone living in an urban area is more often exposed to anthropogenic noise, therefore, they may have a different emotional response. On the other hand, people living in rural areas are more likely to be exposed to natural noises and less often to human-made noise. These differences may significantly change the results of the study.

Exposure-Time: Although a correlation between attitude and noise was demonstrated, there is no way to absolutely claim that this is an effect of noise pollution from solely this study. This study demonstrates that there is a possibility that noise pollution causes emotional responses, but since the noise sample played was only twenty seconds long, it is difficult to prove this theory. Noise pollution consists mostly of constant, long-term exposure; thus, an emotional connection to noise pollution was not proved. What this study does show is that there is a possibility for negative emotional effects as a result of noise pollution. There was a clear change in attitude after listening to the sound for twenty seconds, which is not much time; therefore, a longer exposure time could potentially lead to a stronger response, possibly affecting people's mood.

Noise Samples: Another limitation of this study is the noise samples themselves. Since I went out and recorded the noises myself, I decided what I wanted and did not want the

students to hear. In day-to-day noise pollution, people are not able to control the types of noises they hear. It is possible that the specific noises I chose affect some students more and others less, which could limit the data. The noises were not absolute, nor random, therefore influencing the results. Additionally, pleasant non-human noises and abrasive human noises were recorded. If noises such as storms, winds, or someone singing were recorded, different outcomes may have resulted.

Conclusion

Research Process Reflection

In all, the research process worked well for this study. Through looking at the body of knowledge, a gap in the emotional effects of noise pollution was identifiable. This was seen through multiple studies of scientists only looking at the physical effects, which are harmful nonetheless, but neglecting to consider the emotional effects. After narrowing the scope to surveying middle school art students and realizing it was possible to use drawings to analyze emotions, a behavioral survey was created. A behavioral survey using both survey questions and drawings to compare the attitude shift from two different types of noises was the most viable way to answer the proposed research question: to what extent do natural noises, in comparison to anthropogenic noises, correlate with the attitude of middle school art students in southeastern Virginia? After collecting data and finding a credible art analyzing guide to quantify it, it was feasible to properly detect a shift in attitude from the two noises. It is clear to confirm that both hypotheses were supported through this study.

Impacts on the Field

Future Research: After this study, the next step would be to look at long-term noise exposure effects. This would require more time and resources to conduct, but it would better prove whether noise pollution has emotional effects. By exploring this, the public could be made more aware of the dangers of noise pollution and work harder to prevent exposure.

Another continuation of this study could be looking at different geographic areas. People in urban areas that are more susceptible to noise pollution may either be heavily affected emotionally or immune to it; a deeper investigation into this demographic would be interesting.

Future Infrastructure: Many countries have already begun changing their infrastructure to accommodate noise pollution. Switzerland, for example, made legal changes to combat it. An ordinance named the Noise Abatement Ordinance (NAO), created in 1986 and updated in 2021, aims to limit unwanted sound throughout Switzerland.[17] Figure 6 shows the direct statement from The Swiss Federal Council regarding the purpose of the ordinance.

[1] This Ordinance is intended to protect against harmful and disturbing noise.

[2] It regulates:

a. the limitation of exterior noise emissions caused by the operation of new and existing installations in accordance with Article 7 of the Act;

b. the designation and development of building zones in areas exposed to noise;

c. the issuing of planning permission for buildings with rooms sensitive to noise and lying in areas exposed to noise;

d. the soundproofing against exterior and interior noise of new buildings with rooms sensitive to noise;

e. the soundproofing against exterior noise of existing buildings with rooms sensitive to noise;

f. the determination of the exposure to exterior noise and its rating based on exposure limit values.

Fig. 6. Noise Abatement Ordinance (NOA). Chapter 1 General Provisions. Article 1 Aim and Scope.

After this study and future research, countries may begin to create legislation like that of Switzerland. This study shows how impactful noise is to attitude in just a few seconds, showing that in the long term may cause worse problems. Countries should follow Switzerland's example and make changes to accommodate for noise.

In the private sector, infrastructure companies, such as Bluedot in Canada, are using sustainable practices and natural inspirations when creating urban environments, which is known as green

infrastructure.[2] One technique of green infrastructure is adding plants and 21 trees to urban areas. These resources have the ability to reduce street noise by almost half when used properly. New designs, such as these, aim to combat noise pollution and reduce its effects. The world must realize the dangers of noise pollution and use new technologies to create solutions for problems that have significant impacts on humans, society, and the environment.

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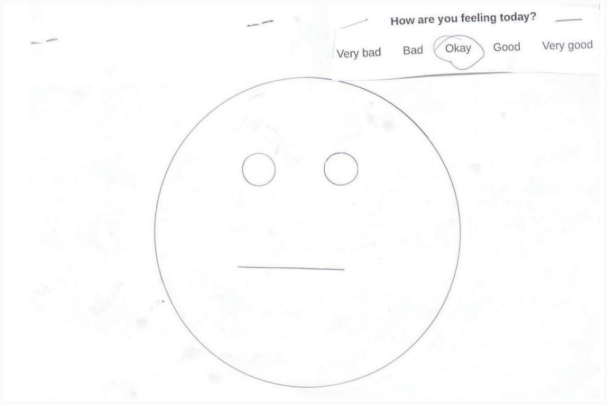
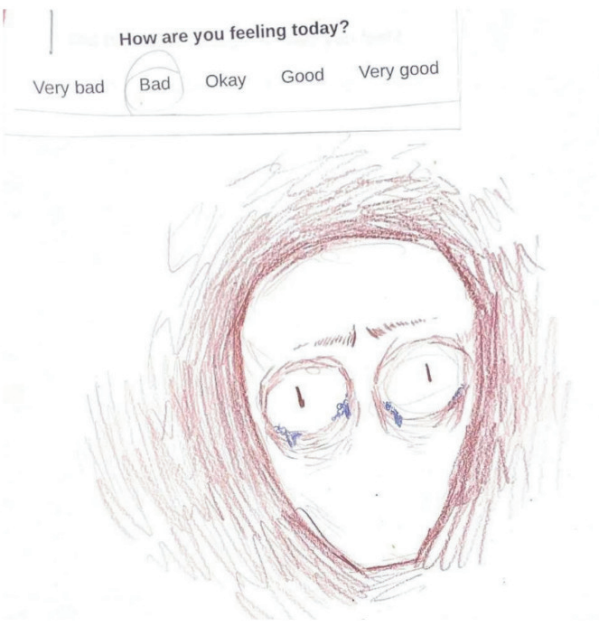
Appendix A

Fully Positive Drawing Drawing made by a student in Class A, a natural noise sampled class. This is the student's neutral drawing, before listening to any noises. The curved lines, sun-shape, light and bright colors, and the answer "good" on the student's survey make this drawing entirely positive.

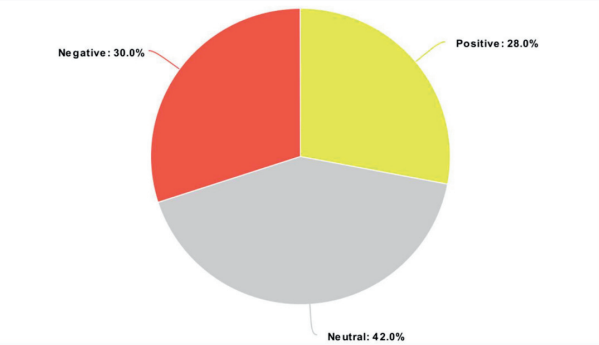


Fully Neutral Drawing Drawing made by a student in Class D, an anthropogenic noise sampled class. This is the student's neutral drawing, before listening to any noises. The plain lines, no light, lack of color, and the answer "okay" on the student's survey make this drawing entirely neutral.

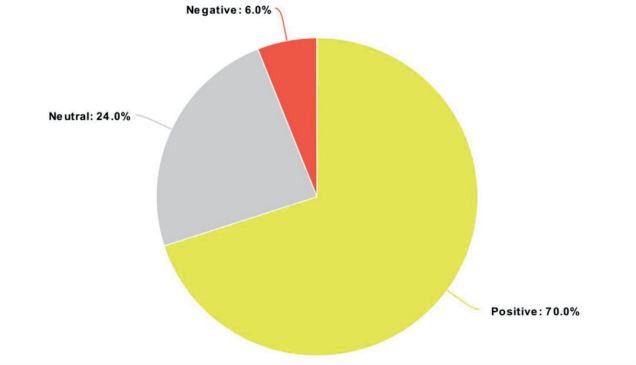


Fully Negative Drawing Drawing made by a student in Class B, a natural noise sampled class. This is the student's neutral drawing, before listening to any noises. The chaotic lines, shadows, dark colors, and the answer "bad" on the student's survey make this drawing entirely negative.

Appendix B

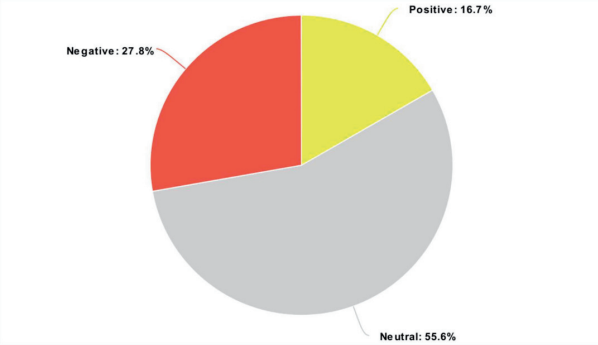


Attitude Reflected in Neutral Drawings for Natural Noise Sampled Classes

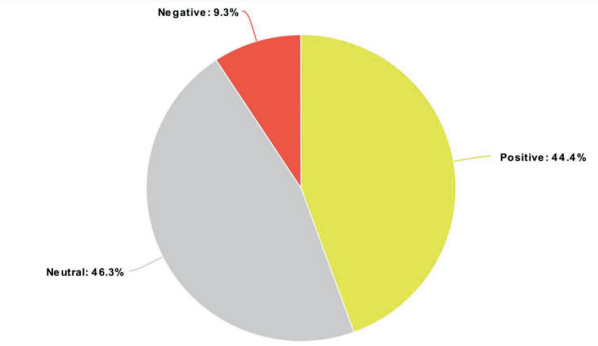


Attitude Reflected in Post-Noise Drawings for Natural Noise Sampled Classes

Appendix C



Attitude Reflected in Neutral Drawings for Anthropogenic Noise Sampled Classes



Attitude Reflected in Post-Noise Drawings for Anthropogenic Noise Sampled Classes

RESEARCH ON THE DEVELOPMENT STRATEGY OF MOBILE SHORT VIDEO - SWOT ANALYSIS BASED ON TIKTOK

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Abstract

In the current digital age, characterized by rapid advancements in technology and increased connectivity, mobile short video platforms have emerged as significant players in the media landscape. This paper focuses on TikTok, a leader among these platforms, whose growth has been notably accelerated by the global shift toward remote interaction during the early 2020 pandemic. The study employs a SWOT analysis—an analytical framework that evaluates the Strengths, Weaknesses, Opportunities, and Threats of a subject—to comprehensively analyze TikTok. This methodical approach helps to identify the strategic positioning and potential future trajectories for TikTok. The findings from this analysis are used to articulate well-founded policy recommendations aimed at enhancing the platform's sustainability and impact in the digital economy. While the recommendations are briefly summarized, they represent actionable strategies grounded in the detailed SWOT analysis provided.

Introduction

With the rapid development of China's economy, consumers' awareness of and demand for mobile short videos are increasing. As a pioneer, TikTok, a musical creative short video platform developed by ByteDance, serves as a community for users of all ages. Through TikTok, users can select songs and create their own musical videos. This paper will focus on TikTok as the subject of research to analyze its strengths, weaknesses, opportunities, and threats, and will propose corresponding strategies. It is hoped that this research will contribute to the robust advancement of mobile short video platforms.

Literature Review

The internet celebrity economy, fueled by advancements in technology and new media, has rapidly evolved into a significant economic sector, drawing an increasing number of participants.[5] The expansion of network communication and information technology has elevated short videos to a pivotal medium in this economy, enhancing user engagement through dynamic, point-to-multipoint communication and the production of compelling content.[3] This dynamic has given rise to the fan economy within short videos—a modern business model that merges technological innovation with commercial strategies, emblematic of the sharing era.[10] In this context, networks and resources are crucial to influencing the progress and strategic approaches of content incubators.

However, the actual dynamics of the relationship between incubators, both domestically (China) and internationally, remain unclear.[13] Researchers like Du Kangyi and Zhao Hongshan have focused on the commercialization phase of short videos to analyze current trends and future developments within the internet celebrity economy.[1] Similarly, Zhai Xiaorui has studied the effectiveness of marketing models influenced by new media.[11] Wang Jiuhe and Sun Danyang have analyzed the short video industry's business model through a value co-creation framework, aiming to reorganize value modules and redefine key elements such as internal mechanisms, integration within value networks, and the formation of a business ecosystem conducive to multi-party value creation.[7] Additionally, Zhou Mengzhen's study on Papitube, a leading Multi-Channel Network (MCN), has focused on strategies for online celebrity engagement, account incubation, and monetization.[15]

TikTok, a prominent player in the internet celebrity economy, has been extensively analyzed. Zhang Jiuhui and colleagues have explored the innovative behaviors of TikTok in technological, marketing, and business model dimensions, employing a mathematical model for a comprehensive evaluation of its innovation capabilities.[12] Furthermore, Li Xiaolei and Li Lin applied Yuan Lei's "3-4-8" business model framework to disect TikTok's strategies, linking them to the broader evolution of short video platforms and Yuan's theories on business model transformation.[4] Jin Honghui and Liu Honghai used TikTok as a case study to develop a marketing framework specifically tailored for furniture companies, providing innovative strategies suitable for this niche market.[2] Wang Jiaxin has investigated the monetization challenges within TikTok's business model, while Wang Kaili has critiqued its current marketing strategies, offering recommendations for enhancement.[6,8] Lastly, Zheng Yandan and associates investigated the involvement of college students in the internet celebrity economy via the TikTok platform, offering recommendations for students, internet celebrity entrepreneurs, and regulators to address the identified issues.[14]

Based on the literature reviewed, this paper is poised to make four principal contributions. Firstly, while many studies have examined video platforms, the analysis of the advantages, disadvantages, and opportunities of mobile short videos within the Internet celebrity economy remains an under-explored subject. This paper aims to

address these gaps by focusing on the development strategies of TikTok, a leading mobile short video platform. Secondly, the paper employs SWOT analysis to discuss TikTok's strengths, weaknesses, opportunities, and threats, offering a structured methodological approach. Thirdly, the research utilizes real and authoritative data to enrich the analysis, ensuring that the findings are comprehensive, current, and accurate. This approach facilitates the drawing of objective and timely economic conclusions. Fourthly, the paper offers targeted policy recommendations to foster the healthy development of the mobile short video sector. It also provides insights from Chinese case studies, facts, and experiences to aid the growth of the mobile short video industry in other developing countries.

SWOT Analysis

The definition of the short video industry varies between academia and industry. This study defines a short video as content filmed, edited, shared, and interacted with using mobile devices and apps based on mobile Internet and smart terminal technology. Typically, these videos range from 30 seconds to 20 minutes in length, with the prime shooting time often falling between 10 seconds and 60 seconds. Short videos facilitate instant dissemination, have a brief production cycle, incur minimal costs, cover extensive content, and ideally exhibit high levels of originality and individuality. They also feature a high degree of netizen participation and represent a flexible form of video-based new media.

TikTok, a subsidiary of ByteDance, is the fastest-growing company in the short video industry. Officially launched on Sept. 20, 2016, TikTok reported that from January to June 2020, the total number of live broadcasts by musicians on its platform exceeded 2 million, attracting over 9.8 billion user views. The platform primarily serves all age groups with a 15-second music short video format and targets contemporary young people as its main audience. Users can create their preferred music-related short video format and targets contemporary young people as its main audience. Users can create their preferred music-related short videos using self-selected music, filters, and beauty effects.

To examine the development strategy of short videos, specifically using TikTok as a case study, this paper employs the SWOT analysis method. Introduced by Professor K.J. Andrews of Harvard Business School in 1971 in "The Concept of Corporate Strategy," SWOT stands for Strengths, Weaknesses, Opportunities, and Threats. Strengths and weaknesses are internal factors, whereas opportunities and threats are external factors. SWOT analysis systematically matches these factors to draw conclusions that significantly inform decision-making processes.

Strength

User-friendliness and accessibility: The platform simplifies both content creation and consumption, making it exceptionally approachable for users across all demographics. For video creators, TikTok offers a streamlined process where they can easily choose from 15-second or 60-second clips, accompanied by a wide array of engaging features such as music, stickers, special effects, and diverse backgrounds. This enables creators to produce content effortlessly right from their smartphones. For viewers, TikTok's interface is intuitively designed, presenting video content immediately upon launching the app. Users can navigate through videos with simple vertical swipes, facilitating a smooth and rapid browsing experience. This ease of use not only enhances user engagement but also fosters a deeper dependency on the platform. Moreover, TikTok significantly enhances user interaction and engagement. The platform enables users to interact with content creators directly through features like comments, likes, and shares, available anytime and anywhere. This immediacy greatly reduces the communication gap between creators and their audience, enhancing the social interaction aspect of the platform and encouraging a vibrant community dynamic.

Robust community attributes: TikTok seamlessly integrates with multiple platforms. Users can effortlessly share their favorite content across popular social networks like Whatsapp, WeChat, and Facebook. Beyond simple content sharing, TikTok enhances networking through features that allow users to connect with real-life acquaintances via address books, geographical locations, and nearby user functions. Additionally, the platform supports the formation of cultural groups based on shared interests, facilitating engaging and equal exchanges among users. This comprehensive social connectivity enables users not only to distribute their favorite videos but also to engage in traditional social interactions such as chatting.

UGC and PGC Coexistence Model: Another significant strength of TikTok is its "UGC (User Generated Content) + PGC (Professional Generated Content)" coexistence model, which sets it apart from other platforms. In this model, professional content (PGC) serves as a catalyst for user-generated content (UGC), enhancing both content quality and user engagement. UGC allows users to independently create and share a variety of content, from text and images to audio and video, fostering a grassroots and expansive content ecosystem. Conversely, PGC is crafted by users who possess specific expertise and achievements, elevating the content's professionalism and appeal. This synergistic model has injected vitality into TikTok, enriching the platform's content diversity and facilitating rapid dissemination among users. The platform hosts a vibrant community of PGC creators like Liudianban, Li Ziqi, Papi Jiang, and Shancunxiaojie, who initially garnered attention with their entertaining videos and subsequently attracted professional teams due to their popularity. This interaction between internet celebrities and their fans not only enhances community engagement but also drives substantial traffic to the platform, significantly boosting user retention and focus on TikTok.

Weakness

Challenges in Content Moderation: TikTok faces significant challenges in controlling content, as the platform frequently hosts videos that promote materialistic values, contain subtle negative messages, or feature content that glorifies revenge-based narratives. Such content often presents distorted value orientations, which can negatively influence viewers, particularly among younger users who are in the critical phase of shaping their personal and social values. The propagation of misguided value systems through these videos is particularly detrimental to this impressionable demographic. Moreover, the platform's reliance on algorithms to recommend content can exacerbate public relations crises. In instances where a company is involved in a controversy, the algorithm-driven promotion of related short videos can rapidly amplify the crisis. This lack of effective content moderation can lead to situations spiraling out of control, damaging the platform's reputation and trustworthiness. Consequently, TikTok's challenge in implementing stringent content controls poses a significant risk, undermining its potential for fostering a safe and positive online community.

Superficial Content and Limited Educational Values: While TikTok offers a wide array of content, much of it gravitates towards entertainment, lacking substantive value or a defined core message. The platform's focus on entertainment and humor can lead to a sense of time wastage and emptiness among users after prolonged viewing, resulting in feelings of regret. Additionally, the constraints on video length—ranging from 15 to 60 seconds—limit the depth of information that can be conveyed, offering only superficial snippets of knowledge. This predominance of light entertainment not only hinders users from engaging in deeper thought but also subtly encourages them to adopt others' viewpoints without critical reflection. These issues restrict TikTok's appeal among demographics that value educational content, such as highly educated and high-spending groups, thus impeding its ability to penetrate these lucrative markets. Moreover, the lack of meaningful content combined with TikTok's compelling data-driven promotions often leads to resistance from concerned parties such as parents and

company managers. Over the long term, this resistance could hinder user retention and growth, as these stakeholders may discourage usage among younger audiences and within professional settings, posing a significant challenge to TikTok's sustained development.

Inadequate Protection of Originality: TikTok struggles with protecting original content, as evidenced by prevalent trends that often lead to numerous imitations and derivatives. This repetition can induce aesthetic fatigue among users, diminishing their desire to engage with the platform. The issue of plagiarism on TikTok is notably severe, with a widespread occurrence of copied content, ideas, and even entire scripts. This issue affects a broad range of creators, from well-known celebrities to amateur enthusiasts. Unfortunately, TikTok currently lacks effective management and enforcement mechanisms to address plagiarism. The platform does not impose significant consequences for copying, with the only immediate feedback coming from fans' comments. This absence of safeguards for original works significantly dampens creators' enthusiasm for producing unique content. As originality wanes and content becomes repetitive, user interest declines markedly, posing a substantial threat to the platform's long-term vibrancy and appeal.

Formation of an 'Information Cocoon': The phenomenon known as the "information cocoon" occurs when users, driven by their preferences and interests, isolate themselves within a self-curated media bubble. This is exacerbated by new media platforms like TikTok, which utilize algorithmic recommendation technologies to promote this trend. On TikTok, users typically select and engage with short videos that align with their interests and are likely to swipe past or block content that does not appeal to them. The algorithmic system on TikTok curates a highly personalized stream of video content, drawing from a vast array of information and pushing it to users based on their previous interactions. Over time, this immersive method of communication encourages users to delve deeper into their preferences, reinforcing their "information cocoon." As a result, users may become more entrenched in their viewpoints and less exposed to diverse perspectives, potentially limiting their understanding and engagement with the broader world.

Opportunity

Significant Market Share Domestically (China) and Internationally: TikTok boasts over 750 million daily active users domestically, with its international version amassing more than 1.5 billion monthly active users. According to Sensor Tower, a data analytics firm, TikTok's Q1 2020 download figures reveal that it generated the most downloads for any app ever in a quarter, accumulating more than 315 million installs across the App Store and Google Play. TikTok has successfully expanded its presence in overseas markets by adopting the strategy of localizing global products. This approach involves adapting to the economic, cultural, and political environments of host countries during the production and business activities of multinational companies. By diluting the characteristics of its home country and integrating local resources such as personnel, capital, products, and technology, TikTok has transformed itself into a genuinely local company in various nations, becoming the first Chinese short video app to gain global popularity.

Fragmentation of Leisure Time: In modern life, the pace is increasingly fast, and the substantial pressures of daily work and life leave people with little patience and time. High job demands and life stresses often prevent individuals from dedicating extended periods to leisure and entertainment activities. Consequently, people tend to utilize fragmented periods of entertainment time, such as during commutes or meal breaks. The scarcity of leisure time severely limits the choices available for entertainment. In this context, the emergence of TikTok offers an excellent alternative for these brief interludes. Additionally, TikTok's convenient video switching feature has proven to be highly popular, allowing users to easily navigate and consume content in short, manageable segments. This alignment with modern lifestyle patterns presents a

significant opportunity for TikTok's continued growth and engagement.

Mature Big Data Analysis Technology: With the continuous advancement of big data analysis technology, TikTok has developed powerful data analysis capabilities that enable it to precisely understand audience preferences. Accurate analysis and targeted content delivery are enhancing user affinity for TikTok. The maturity of these technical capabilities has injected substantial vitality into the market, fostering the growth of various industries. Backed by Jinri Toutiao, a social media platform under the same parent company, TikTok benefits from robust algorithms that facilitate refined analysis and precise content recommendations, significantly enhancing the user experience. As big data analysis technology continues to evolve, TikTok's ability to fine-tune its user targeting will further improve, strengthening its market position.

Opportunity in Revenue Trends: Revenue from the software business, software products, and information technology services reflects the dynamic development of the industry. Figure 1 illustrates the development trends of these variables in China from 2010 to 2020. Average exchange rate in 2020 reflect that 1 RMB is approximately 0.14 USD. Table 1 provides a descriptive statistical analysis of these revenue streams over the same period. The

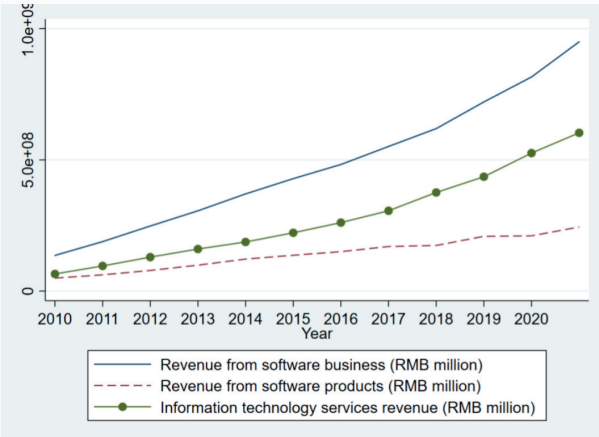

Fig. 1. Trends in Revenue from Software Business, Software Products, and Information Technology Services in China (2010-2020); Data source: National Bureau of Statistics of China

Variable	Obs	Mean	Std.Dev.	Min	Max
Revenue from software business (RMB million)	12	4.850e+08	2.550e+08	1.360e+08	9.500e+08
Revenue from software products (RMB million)	12	1.420e+08	6.240e+07	4.930e+07	2.440e+08
Revenue from information technology services (RMB million)	12	2.810e+08	1.730e+08	6.530e+07	6.030e+08

Table 1. Descriptive Statistical Analysis of Revenue from Software Business, Software Products, and Information Technology Services in China (2010-2020); Data source: National Bureau of Statistics of China

standard deviations are notably high at 2.550e+08, 6.240e+07, and 1.730e+08, respectively, indicating significant volatility and dispersion in these variables across the past decade. This variability underscores the rapid pace of development in China's internet sector.

Mass Production of Short Videos: With the rapid advancement of science and technology, digital traffic has become a significant dividend of this era. The allure of internet fame and its associated benefits has captivated many. Countless ordinary individuals aspire to such opportunities that could potentially transform their lives. Take the example of Zhangtongxue, a TikTok blogger from Yingkou City, Liaoning Province, born in 1986. He specializes in creating rural sitcoms. His videos may lack picturesque scenery, advanced special effects, or even popular background music. However, the unique depiction of rural life in Northeast China offers a distinct splendor that resonates with netizens. As of December 7, 2021, just about two months after starting to post on TikTok, Zhangtongxue has amassed over 14 million followers on Douyin. His life was profoundly transformed by his engagement with TikTok, showcasing the platform's potential to significantly impact individuals' lives through content creation.

Improvement in Human Quality: According to the "2020 TikTok Live Data Map," educational live broadcasts on TikTok saw an increase of 110% compared to December 2019, with the number of live broadcast views surging by 550%. Furthermore, the TikTok Research Report released by Beijing News New Media in October 2018 highlights that users under

the age of 24 constitute 75.5% of the platform's demographic. Regarding educational background, 41.9% of TikTok users possess at least a bachelor's degree, and 67.8% have attained a college degree or higher. The operators of cultural and educational accounts on TikTok are typically cultural figures, renowned educators, vocational instructors, and official cultural and educational institutions. By fostering a multidimensional and enriched short video content ecosystem, college oriented TikTok accounts provide high-quality, diverse, and innovative videos and live broadcasts. This content aids teachers and students in acquiring knowledge, appreciating art, expanding their horizons, exploring the world, and realizing the educational value offered by the TikTok platform.

Increasing Human Capital: The average number of college students per 100,000 population reflects the level of human capital. Figure 2 illustrates the development trend of this variable in China from 1978 to 2021. As depicted in Figure 2, the number of college students per 100,000 population in China has shown a consistent upward trend, with a significant increase after 2001. By 2021, the overall number exceeded 3,000, marking a qualitative leap and indicating a substantial rise in the level of human capital. Table 2 presents the descriptive statistical analysis of the average number of college students per 100,000 population in China from 1978 to 2021. The standard deviation is 1051, suggesting that this variable has been highly discrete and volatile over the past 40 years, further highlighting the rapid development of China's educational sector. A comparison of the maximum and minimum data reveals that the average number of college students per 100,000 population has surged from 89 in 1978 to 3,301 in 2021, demonstrating significant growth over the past four decades.

Variable	Obs	Mean	Std.Dev	Min	Max
The average number of college students per 100000 population in China	44	1188	1051	89	3301

Table 2. Descriptive statistical analysis of an average number of college students per 100000 population in China, 1978-2021. Data source: National Bureau of Statistics of China

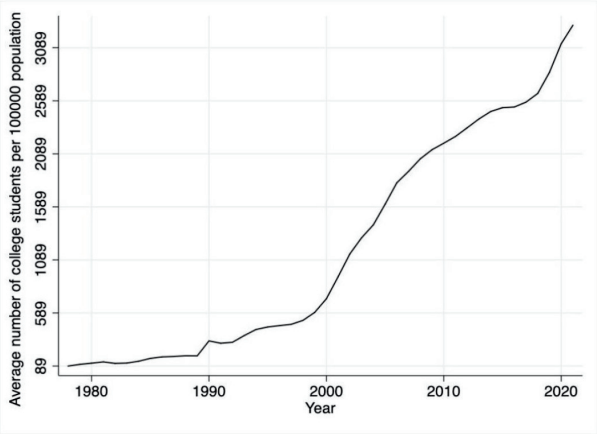

Fig. 2. Average number of college students per 100000 population in China from 1978 to 2021 (people), Data source: National Bureau of Statistics of China

Threat

Lack of User Retention: In the new era, mobile intelligent devices and internet businesses are rapidly evolving, thrusting the media information industry into a vibrant new media era characterized by rapid changes. The content offered by short videos tends to be relatively simplistic and can quickly become monotonous. Moreover, the turnover rate of content in the short video industry is exceptionally high. For instance, the Kuaishou App, which was popular in 2017, was overtaken by TikTok in 2018. This shift was largely due to the homogeneity of video content across these platforms, which resulted in weak user retention. If TikTok cannot address this issue of content differentiation, it risks being supplanted by emerging platforms in the future.

High Cost and Complexity of Video Moderation: TikTok's review mechanism primarily relies on algorithmic screening, supplemented by manual review. Videos initially undergo an algorithmic check, and those that fail this step are forwarded for manual review. If a video fails manual scrutiny, it must be re-edited and resubmitted. Although this process addresses certain issues, it poses a significant challenge given TikTok's daily active user base of 400 million and a minimum of one million videos uploaded daily. While the algorithm handles most reviews, a substantial number still require manual examination. Consequently,

SWOT	Content
Strengths	(1) User-friendliness and accessibility (2) Robust community attributes (3) UGC and PGC Coexistence Model
Weaknesses	(1) Challenges in content moderation (2) Superficial content and limited educational values (3) Inadequate protection of originality (4) Formation of an 'Information Cocoon'
Opportunities	(1) Significant market share domestically (China) and internationally (2) Fragmentation of leisure time (3) Mature big data analysis technology (4) Mass production of short videos (5) Improvement of human quality (6) Increasing human capital
Threats	(1) Lack of user retention (2) High cost and complexity of video moderation

Table 3. Summary of Analysis

TikTok employs a manual review team of over 3,000 individuals. For any internet company, maintaining such a large team represents a considerable expense and could seriously impede TikTok's development.

Conclusions and Policy Recommendations

The rapid ascent of live streaming platforms marks a significant trend in the development of the Internet economy and the internet celebrity economy. Established in 2016, TikTok has emerged as a leader among these platforms. This paper uses TikTok as a case study to explore the advantages, disadvantages, opportunities, and threats in its development process through SWOT analysis. The aim is to use this analysis as a reference point to foster the healthy development of live streaming platforms. The specific conclusions are presented in Table 3.

Based on the above conclusions, this paper offers the following policy recommendations: First, TikTok should actively seek partnerships with film and television companies to foster an ecosystem that respects and enhances intellectual property rights. By facilitating a collaborative space, TikTok can empower content creators to legally utilize copyrighted materials in their videos. This approach not only supports the original creators through proper attribution and compensation but also enhances the content quality on TikTok, attracting a more diverse audience base. Second, TikTok needs to develop and enforce a comprehensive anti-plagiarism framework. This should include advanced content monitoring technologies to detect and flag plagiarized content automatically. Beyond just banning accounts, TikTok should consider implementing a tiered response system where penalties correspond to the severity and frequency of the infringement. Additionally, educational initiatives should be launched to inform creators about intellectual property rights and the implications of copyright infringement. Third, TikTok could introduce incentives for educational content creators, such as grants or revenue-sharing models that favor educational videos. By promoting content that is not only entertaining but also informative, TikTok can broaden its user base and increase engagement, particularly among those seeking self-improvement and learning opportunities. Fourth, TikTok has significant opportunity in promoting local content creators who can produce culturally relevant content. By supporting these creators through localized marketing initiatives and creator funds, TikTok can ensure richer and more diverse content that resonates with users on a regional level.

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THE RELATIONSHIP BETWEEN EARLY LIFE ADVERSITY AND EMOTION REGULATION IN DIFFERENT DIMENSIONS: SLEEP QUALITY AS A MEDIATOR

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Abstract

Early life adversity (ELA) adversely impacts individuals' emotional and physical health by affecting their ability to regulate emotions. ELA is associated with alterations in the stress response system, influencing behavioral and cognitive responses to negative life events in later stages. This study aims to explore the relationship between early life adversity and emotion regulation, considering sleep quality as a moderating factor. We recruited 424 participants with relatively low ELA scores. Our findings indicate that ELA is linked to an increased use of ineffective emotion regulation strategies in response to adversity. Notably, threats within the ELA subcategories had a more significant impact on emotion regulation strategies than deprivation. Additionally, sleep quality played a mediating role between both the threat and deprivation components of ELA and emotion regulation effectiveness. Specifically, sleep quality mediated the effects of deprivation on ineffective emotion regulation and the effects of threat on effective emotion regulation. The distinct influence levels of the ELA subcategories (threat and deprivation) on emotion regulation were also delineated. This study underscores the importance of considering both ELA and sleep quality in future research on emotion regulation strategies.

Introduction

Early life adversity (ELA) encompasses a range of adverse experiences, including, but not limited to parental separation and physical abuse, that individuals may encounter early in life.[5] Previous research has established a strong association between exposure to ELA and emotion regulation. Emotion regulation is the process through which individuals attempt to influence their own or others' emotional states. This process often includes cognitive appraisal, a mechanism where thoughts about a situation are adjusted to alter emotional responses.[12] Individuals often engage in strategies to down-regulate negative emotions, such as diminishing their intensity, and up-regulate positive emotions, driven by a natural desire for positive emotional experiences. Moreover, they manage their emotions by adjusting the duration and quality of emotional responses. Emotion regulation key strategies include situation selection, situation modification, attentional deployment, cognitive change, and response modulation.[6]

Exposure to early life adversity can significantly impact these emotion regulation strategies. ELA may impair the negative-feedback control of the hypothalamic-pituitary-adrenal (HPA) axis by glucocorticoids, lead to alterations in glutamate neurotransmission, and decrease hippocampal neurogenesis.[10] The HPA axis, integral to the body's stress response system, orchestrates the release of glucocorticoids (cortisol in humans) in response to stress. Glucocorticoids are steroid hormones that manage the body's response to stress by regulating inflammation and affecting various bodily functions, including immune response and metabolism. Dysfunction in this system can lead to an impaired ability to regulate stress, which in turn can impact emotional regulation.[4] Glutamate neurotransmission refers to the process where glutamate, the primary excitatory neurotransmitter in the nervous system, facilitates the transmission of nerve signals. Changes in this process can affect brain function and emotional responses.

Moreover, children who have experienced physical abuse often have reduced hippocampal volumes and smaller amygdalae. These were related to the expression of behavioral problems and interference with children's emotional processing and regulation later in their lifetime.[7] Furthermore, early life adversity increases the likelihood of experiencing anhedonia, defined as a decreased capacity to feel pleasure, which in turn can exacerbate various emotional disorders and alter the functioning of reward networks in the amygdala.[3] Past research has illustrated that a deeper understanding of our emotions can result in better regulation.[2] Therefore, anhedonia as a result of early life adversity can negatively affect individuals' emotion regulation.

However, different subcategories of ELA tend to exert different influences on emotion regulation. Deprivation and threat, as subcategories of ELA, have been demonstrated to have distinct effects on emotion regulation. Threats can cause children to experience difficulties in adapting to emotional conflict and differences in the coupling of the amygdala and pregenual anterior cingulate cortex when responding to various negative events. Moreover, threats have been found to lead to an inhibition of responses in individuals toward emotional stimuli. In comparison, deprivation has been related to deficits in individuals' cognitive control rather than automatic emotion regulation.[9] Additionally, while exposure to threats has been found to be related to expressive flexibility, deprivation typically has not shown such an association.[15]

Nonetheless, many unexpected factors affect the relationship between ELA and emotion regulation. For instance, sleep quality has been often found to be associated with emotion regulation. Lower sleep quality has been related to lower cognitive reappraisal, indicating a negative effect on emotion regulation.[11]

Goal & Hypothesis

The purpose of this study is to:

- Identify a correlation between ELA and emotion regulation.
- Differentiate the influences of different subcategories included in the ELA on emotion regulation.
- Determine the role of sleep in the relationship between ELA and emotion regulation.

Hypotheses

Hypothesis 1: Higher ELA score is related to worse emotion regulation.

Hypothesis 2: Sleep quality mediates the relationship between ELA and emotion regulation.

Hypothesis 3: There is a stronger association between emotion regulation and deprivation compared to threats and emotion regulation.

Methods

Participants

Requests for participation were primarily distributed via a Qualtrics link through various social media platforms including WhatsApp, Facebook, Instagram, and WeChat. Participants were excluded from the final data collection if they were under 18, had been diagnosed with a mental disorder, or were using psychotic medication at the time. Initially, 849 participants were enrolled; however, the final sample size was 424, comprising 316 females and 108 males. The reduction in sample size was attributed to 244 participants not completing the survey, 149 failing a catch trial where they were instructed to select a specific response, 27 being under 18, and 5 diagnosed with mental health issues and on psychological medication.

Procedure

Random participants completed a survey on Google Qualtrics. The questionnaire gathered demographic information, including age, gender, highest level of education completed, mental health diagnosis, and current medication use. Subsequently, participants completed the Childhood Trauma Questionnaire, the Cognitive Emotion Regulation Questionnaire, and the Pittsburgh Sleep Quality Index.

Measurements

Maltreatment Experience

Early life adversity was assessed using the Childhood Trauma Questionnaire, which consists of 28 items across six subscales: emotional abuse, physical abuse, sexual abuse, emotional neglect, physical neglect, and minimization/denial. The CTQ was chosen for its comprehensive coverage of childhood trauma and its well-documented psychometric properties, including high internal consistency and strong predictive validity. This tool allows for a detailed assessment of the severity and type of adversity, enabling a nuanced analysis of how different forms of ELA impact emotion regulation. The minimization/denial subscale was excluded from this study as it does not directly measure maltreatment but rather screens for underreporting. Each remaining item was rated on a five-point Likert scale from 1 (never true) to 5 (very often true), with total scores ranging from 25 to 125 across 25 questions. Deprivation was assessed with 10 questions (score range: 10-50), and threat with 15 questions (score range: 15-75), maintaining a high internal consistency (Cronbach's $\alpha = .95$).

Emotion Regulation Strategies

Emotion regulation was measured using the Cognitive Emotion Regulation Questionnaire, which includes 36 items across nine categories: self-blame, acceptance, rumination, positive refocusing, refocusing on planning, positive reappraisal, putting into perspective, catastrophizing, and blaming others. The CERQ was utilized to measure people's capacity to utilize emotion regulation strategies cognitively after experiencing stressful or threatening events in their lives. Individuals' thoughts instead of their actual behavior in responding to the events were primarily measured by this questionnaire. Responses were rated on a five-point scale from 1 (rarely) to 5 (almost

always) in response to how likely participants would use each strategy in response to a negative life event, with total scores ranging from 36 to 180. This questionnaire's consistency and reliability were confirmed with a Cronbach's alpha above .70.

Sleep Quality

Sleep quality was assessed using the Pittsburgh Sleep Quality Index, which includes 19 items covering seven aspects of sleep: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. The PSQI was utilized due to its comprehensive evaluation of sleep quality aspects and its widespread use in both clinical and non-clinical populations. The global score provides a thorough measure of sleep quality, which is crucial for investigating its role as a mediator between ELA and emotion regulation. This tool's reliability and validity enhance the study's accuracy in linking sleep patterns with psychological outcomes. Responses were rated on a four-point scale from 0 (no difficulty) to 3 (severe difficulties), with total scores ranging from 0 to 57. The validity and reliability of this questionnaire have been confirmed with a Cronbach's alpha between 0.64 and 0.82.[1]

Statistical Analysis

Data analysis was conducted using R Studio. Multiple regression analysis was used to examine the relationship between early life adversity and emotion regulation, using the CTQ scores (excluding the minimization /denial subscale), with separate sum scores for the deprivation and threat dimensions as independent variables, and the sum score of the CERQ as the dependent variable. Mediation analysis was conducted to determine the impact of sleep quality on the relationship between emotion regulation and ELA, using PSQI scores as the mediator variable, CTQ scores as the independent variable, and CERQ scores as the dependent variable.

Results

Demographic characteristics

The demographic traits of the study participants are presented in Table 1. The sample consisted of 316 females (74.5%) and 108 males (25.5%). Despite the difference in the number of participants across genders, no significant differences were found in the measured variables, including CTQ scores, effective emotion regulation, ineffective emotion regulation, and PSQI scores, between males and females. This suggests that gender did not significantly influence the outcomes related to early life adversity, emotion regulation, or sleep quality within this sample.

Table 1. Demographic characteristics of the participants

Sample Characteristics	*n*	%	Age		CTQ		Effective emotion regulation		Ineffective emotion regulation		PSQI	
Gender			*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Female	316	74.5	20.54	4.46	33.06	8.94	19.59	2.37	11.07	2.01	4.80	2.95
Male	108	25.5	20.22	2.90	33.19	8.87	19.28	2.61	10.97	1.81	4.71	3.24

Note: N=424

Table 1. Demographic characteristics of the participants

Demographic characteristics

The demographic traits of the study participants are presented in Table 1. The sample consisted of 316 females (74.5%) and 108 males (25.5%). Despite the difference in the number of participants across genders, no significant differences were found in the measured variables, including CTQ scores, effective emotion regulation, ineffective emotion regulation, and PSQI scores, between males and females. This suggests that gender did not significantly influence the outcomes related to early life adversity, emotion regulation, or sleep quality within this sample.

Relationship between ELA sum score and emotion regulation

Linear regression analysis was conducted to explore the relationship between the ELA sum score and emotion regulation strategies. The analysis revealed a statistically significant relationship specifically with the use of ineffective emotion regulation strategies [$F(1, 422) = 40.38$, $p < 0.001$]. Figure 1 identifies a

positive relationship between the two variables. As the ELA sum score increased, there was a corresponding increase in the frequency of ineffective emotion regulation [$\beta = 0.065$, $t(423) = 6.354$, $p < 0.001$, $R^2 = 0.0873$]. This suggests that approximately 8.73% of the variance in ineffective emotion regulation can be accounted for by the ELA sum score, indicating a modest but significant effect. This pattern highlights the impact of early life adversity on the tendency to adopt fewer effective strategies for managing emotions.

Relationship between deprivation, threat, and emotion regulation

Furthermore, linear regression analysis was employed to assess the relationship between deprivation and emotion regulation to discern the level of influence on emotion regulation strategies. The analysis showed that the relationship between deprivation and the frequency of ineffective emotion regulation was statistically significant [$F(1, 422) = 14.52$, $p < 0.001$]. As depicted in Figure 2, deprivation was positively correlated with ineffective emotion regulation, indicating that an increase in deprivation levels was associated with an increase in the use of ineffective emotion regulation strategies [$\beta = 0.068$, $t(423) = 3.81$, $R^2 = 0.0333$]. Thus, deprivation accounts for approximately 3.33% of the observed variation in ineffective emotion regulation.

The relationship between threat and emotion regulation was assessed using a linear regression model. The analysis confirmed that threats have a statistically significant

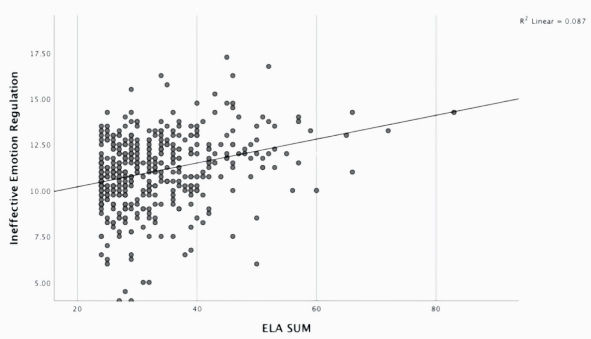

Fig. 1. The relationship between ELA sum score and ineffective emotional regulation

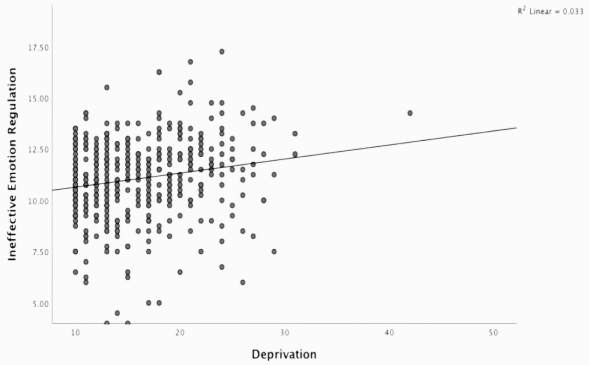

Fig. 2. The relationship between deprivation and ineffective emotion regulation

relationship with the frequency of both ineffective and effective emotion regulation. As illustrated in Figure 3, there is a positive correlation between threat and the frequency of ineffective emotion regulation [$F(1, 422) = 58.5$, $p < 0.001$]. An increase in exposure to threat during childhood is associated with an increase in the use of ineffective emotion regulation strategies in later life [$\beta = 0.142$, $t(423) = 7.468$, $R^2 = 0.122$]. In comparison, exposure to threat has a more substantial influence than deprivation, accounting for about 12.2% of the observed variation in ineffective emotion regulation.

Conversely, Figure 4 demonstrates that an increase in exposure to threats is also associated with an increase in the use of effective emotion regulation strategies [$\beta = 0.0651$, $t(423) = 2.677$, $p < 0.001$]. Threats account for approximately 1.67% of the observed variation in effective emotion regulation, which though significant, suggests a more modest impact compared to their influence on ineffective strategies [$F(1, 422) = 7.165$, $R^2 = 0.0167$].

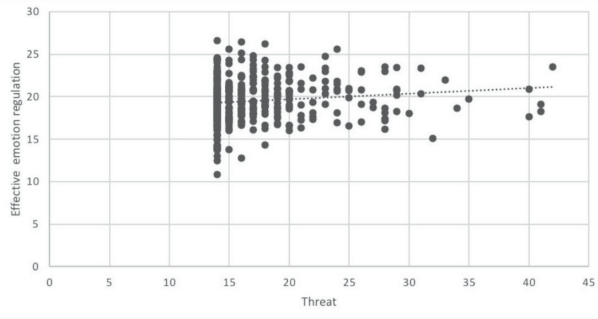

Fig. 3. The relationship between threat and ineffective emotion regulation

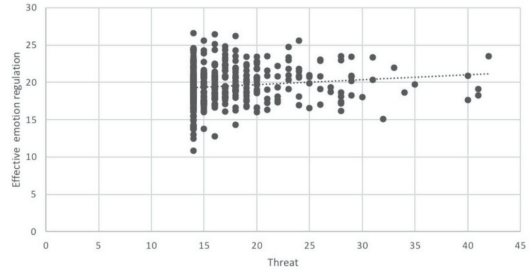

Fig. 4. The relationship between threat and effective emotion regulation

The effect of mediator sleep quality in the relationship between deprivation and ineffective emotion regulation

A mediation model was employed to assess the influence of sleep quality on the relationship between deprivation and ineffective emotion regulation. The results indicated a significant relationship between deprivation and sleep quality ($\beta = 0.189$, $p < 0.001$), as shown by path 1 in Figure 5. An increase in deprivation was associated with poorer sleep quality. Additionally, a significant relationship was found between sleep quality and ineffective emotion regulation ($\beta = 0.203$, $p < 0.001$), depicted by path 2 in Figure 5, where poorer sleep quality correlated with a higher frequency of ineffective emotion regulation strategies. A direct relationship was also noted between deprivation and ineffective emotion regulation ($\beta = 0.0685$, $p < 0.001$), represented by path 3 in Figure 5. After accounting for the impact of sleep quality, the complete mediation effect of sleep quality on the relationship between deprivation and ineffective emotion regulation was revealed ($\beta = 0.301$, $p = 0.0981$), illustrated by path 4 in Figure 5.

The effect of mediator sleep quality in the relationship between threat and emotion regulation

Two mediation models were utilized to explore the effects of sleep quality on the relationships between threat and both types of emotion regulation. Initially, a significant relationship was established between threat and sleep quality ($\beta = 0.225$, $p < 0.001$), as depicted in path 1 of Figure 6. An increase in exposure to threats was associated with worse sleep quality. Furthermore, a significant relationship was found between sleep quality and ineffective emotion regulation ($\beta = 0.160$, $p < 0.001$), shown as path 2 in Figure 6. Poor sleep quality contributed to an increase in ineffective emotion regulation. In addition, there was a significant positive relationship between threat and ineffective emotion regulation ($\beta = 0.142$, $p < 0.001$), shown as path 3 in Figure 6. However, even excluding the impact of sleep quality, a significant positive relationship persisted between threat and ineffective emotion regulation ($\beta = 0.106$, $p < 0.001$), shown as path 4 in Figure 6.

Additionally, Figure 7 illustrated a significant relationship between threat and sleep quality ($\beta = 0.225$, $p < 0.001$), as shown in path 1. Worse sleep quality was also correlated with

Path 1: the relationship between deprivation and sleep quality.

Path 2: the relationship between sleep quality and ineffective emotion regulation.

Path 3: the relationship between deprivation and ineffective emotion regulation.

Path 4: the relationship between deprivation and ineffective emotion regulation excluding the effect of sleep quality

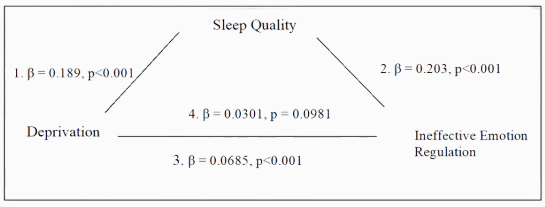

Fig. 5. The effect of sleep quality on the relationship between deprivation and ineffective emotion regulation

Path 1: the relationship between threat and sleep quality.

Path 2: the relationship between sleep quality and ineffective emotion regulation.

Path 3: the relationship between threat and ineffective emotion regulation.

Path 4: the relationship between threat and ineffective emotion regulation excluding the effect of sleep quality.

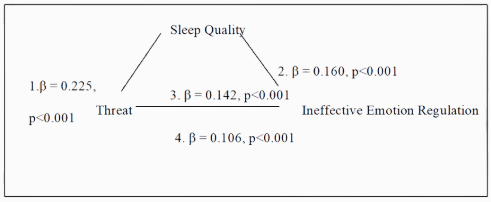

Fig. 6. The effect of sleep quality on the relationship between threat and ineffective emotion regulation

Path 1: the relationship between threat and sleep quality.

Path 2: the relationship between sleep quality and effective emotion regulation.

Path 3: the relationship between threat and effective emotion regulation.

Path 4: the relationship between threat and effective emotion regulation excluding the impact of sleep quality.

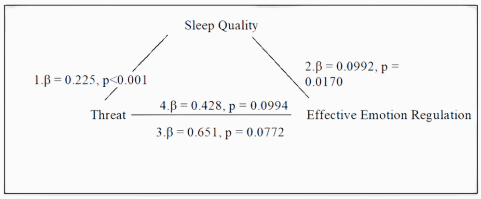

Fig. 7. The effect of sleep quality on the relationship between threat and effective emotion regulation

more effective emotion regulation strategies (β = 0.0992, p = 0.0170), shown as path 2. Moreover, an increase in exposure to threats was related to more effective emotion regulation (β = 0.651, p = 0.00772), demonstrated as path 3. Excluding the effect of sleep quality, this relationship became statistically insignificant (β = 0.428, p = 0.0994), as shown in path 4 of Figure 7.

Discussion

Previous research has demonstrated multiple effects of early life adversity (ELA) on individuals, including increased vulnerability to mental illness and impairment in brain areas associated with emotion regulation. This study focuses on delineating the relationship between ELA and emotion regulation across several dimensions. Specifically, we examined the relationships between deprivation, threat, and both ineffective and effective emotion regulation strategies.

Our first hypothesis was confirmed, with data indicating that higher levels of ELA were associated with poorer emotion regulation, aligning with prior studies. A potential explanation for this finding is the dysfunction of the stress system. Individuals exposed to early life adversity, including stress and abuse, experienced impairments in the stress system, leading to poorer emotion regulation strategies.[4] Chronic stress may also impair activities in the prefrontal cortex and result in decreased cognitive flexibility in adulthood.[8] Additionally, major disruptions in emotional and behavioral regulation could occur as a result of ELA exposure.[14]

The second hypothesis was also supported. Threats had a greater impact on emotion regulation than deprivation. This could be because threats are often associated with more frequent use of disengagement strategies, potentially influencing the development of future psychopathologies.[13] Another reason might be that threats lead to an inhibition of responses to emotional stimuli, which could result in ineffective emotion regulation strategies.[9] Additionally, threats were linked to expressive flexibility,[16] and individuals who are inflexible in expressing their emotions might face challenges in regulating their emotions compared to others.

The third hypothesis was partially confirmed. In this study, sleep quality mediated the relationship between deprivation and ineffective emotion regulation, and between threat and effective emotion regulation. One possible explanation for this outcome is the critical role of sleep quality in emotion regulation. Poor sleep quality can lead to an increase in negative emotions, which negatively affects an individual's ability to regulate emotions.[15] The initially identified relationship between threat and effective emotion regulation might be attributed to the nature of the sample in this study. With scores ranging from 25 to 125 on the CTQ, the average participant score was around 30, indicating a relatively healthy sample, which might account for this observed relationship.

Limitations

While the relatively large sample size was a strength of this study, several limitations should be considered in future research. First, the sample predominantly comprised individuals from China, which introduces a limitation in cultural representation. The findings of this study may not be generalizable to populations with different cultural backgrounds, as cultural norms influence ideal and focal emotions, potentially affecting individuals' emotion

regulation strategies. Furthermore, participants' responses could be influenced by social norms, leading them to modify their answers to conform to socially desirable responses, thus not accurately reflecting their true emotion regulation strategies. Additionally, memory bias may have impacted participants' responses. This bias can lead individuals to alter their memories to align with their current beliefs or attitudes. Consequently, those with effective emotion regulation strategies might reconstruct their memories to present a more positive childhood, while those with ineffective strategies might portray a more negative one. Another limitation is the overall low scores on the Early Life Adversity (ELA) scale, suggesting that the sample may not adequately represent individuals with high levels of ELA. This could make it difficult to identify strong relationships between ELA and emotion regulation. Lastly, the gender distribution within the study was skewed, with 74.5% females and only 25.5% males. This disparity raises concerns about the potential impact of gender on emotion regulation strategies. Although no significant gender effects were observed in this study, the underrepresentation of males could limit the applicability of the findings across genders. These limitations highlight the need for more culturally diverse samples, methods to mitigate social desirability and memory biases, and balanced gender representation in future studies to enhance the generalizability and reliability of the findings.

Future Directions

In conclusion, this study has provided insights into the relationship between early life adversity (ELA) and emotion regulation, highlighting how ELA impairs emotion regulation strategies and how this impact varies between types of adversity such as threats versus deprivation. Immediate implications of these findings include the potential for developing targeted interventions that address specific types of adversity. For example, interventions could be tailored to mitigate the impact of threats on emotion regulation, possibly through resilience training or therapy focused on response inhibition and management of fear responses. Additionally, the moderating role of sleep quality suggests that improving sleep could serve as a preventive or corrective measure to support better emotion regulation in individuals exposed to ELA. This could be immediately actionable in clinical settings where sleep hygiene and therapy could be integrated into treatment plans for those at risk due to their early life experiences. To deepen our understanding of these dynamics, future research should explore longitudinal studies that track the long-term effects of ELA on emotion regulation over time. This could help in understanding the causal relationships and the persistence of these effects into adulthood. Further, considering the environmental and parental influences on emotion regulation could open avenues for community-based interventions and family therapy programs that aim to modify the environmental factors contributing to ELA. Research into how changing these mediating factors might promote healthier emotional development could be crucial for preventative healthcare. Lastly, the global applicability of these findings calls for a broader scope of research involving diverse cultural groups. Such studies could help in designing culturally sensitive interventions that are more effective across different societal norms and values, ultimately leading to strategies that are universally effective. Expanding on these future directions not only provides a clearer path forward for research but also aligns with the practical applications of this study, demonstrating its potential impact on both theory and practice in the fields of psychology and mental health.

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New Research Opportunities

Prairie Research Institute

INHS is seeking Undergraduate Students to work on research projects related to the ecology, behavior, and management of corn and soybean insect pests, principally western corn rootworm beetles or larvae in corn, soybean, or other crops. More information can be found on the Virtual Job Board.

Cline Center for Advanced Social Research

The Cline Center is looking for highly motivated, independent-minded, decisive, and detail-oriented current undergrad UIUC students (preferably in political science) to identify events and event attributes relevant to fatal police encounters primarily within the United States. More information can be found on the Virtual Job Board.

Civil and Environmental Engineering

The Department of Civil and Environmental Engineering is looking for undergraduate students to work on a research project focused on developing an educational game in the adventure game genre for undergraduate students to teach basic concepts of crystalllography such as crystallographic points, directions, and Miller Indices. More information can be found on the Virtual Job Board.

Funding Opportunities

Summer Undergraduate Research Fellowships

The university offers a variety of SURF opportunities through programs such as the Mayo Clinic-Illinois Allianace and the School of MCB. SURF programs allow students to conduct research over the summer by providing students with necessary funding.

Funding and Grants Database

The Office of the Vice Chancellor for Research and Innovation hosts a database of various scholarship and research funding opportunities that is frequently updated. The research grants cover a wide variety to topics and niches.

General Research Opportunities

URAP

The Undergraduate Research Apprenticeship Program offers students with little to no research experience the opportunity to participate in mentored research on campus. Along with conducting research, students learn the fundamentals of the research process and have the opportunity to present at the Undergraduate Research Symposium. Applications typically are due in October.

Grainger ISUR Program

The Grainger College of Engineering Illinois Scholars Undergraduate Research (ISUR) Program offers a structured 2-semester research experience within a learning community. Undergraduate students have the opportunity to learn more about the research process, while also developing skills as they explore opportunities regarding graduate school.

Summer Research Programs

Washington University School of Medicine

WashU Medical School offers a wide variety of research opportunities for students interested in pursuing a career in medicine or clinical research. The programs provide the opportunity to attend seminars hosted by distinguished faculty and doctors, along with collaborating with students from across the country. Applications are typically due in February for the summer.

Health Equity Research Experience (Mayo)

The Mayo Clinic-Illinois Alliance offers 2 undergraduate students the opportunity to conduct research examining health equity through a 10-week summer program at Mayo Clinic. Participants will work to address health disparities through mentored research and community-based learning. Applications for the summer are typically due in January.

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