brainSTEM

ISSUE 03

Ella Gambell - Jack Jones - Michael Kihanya - Becca Marx - Finn McGuinness

Cover art by Ella Gambell

WELCOME.

Dear readers,

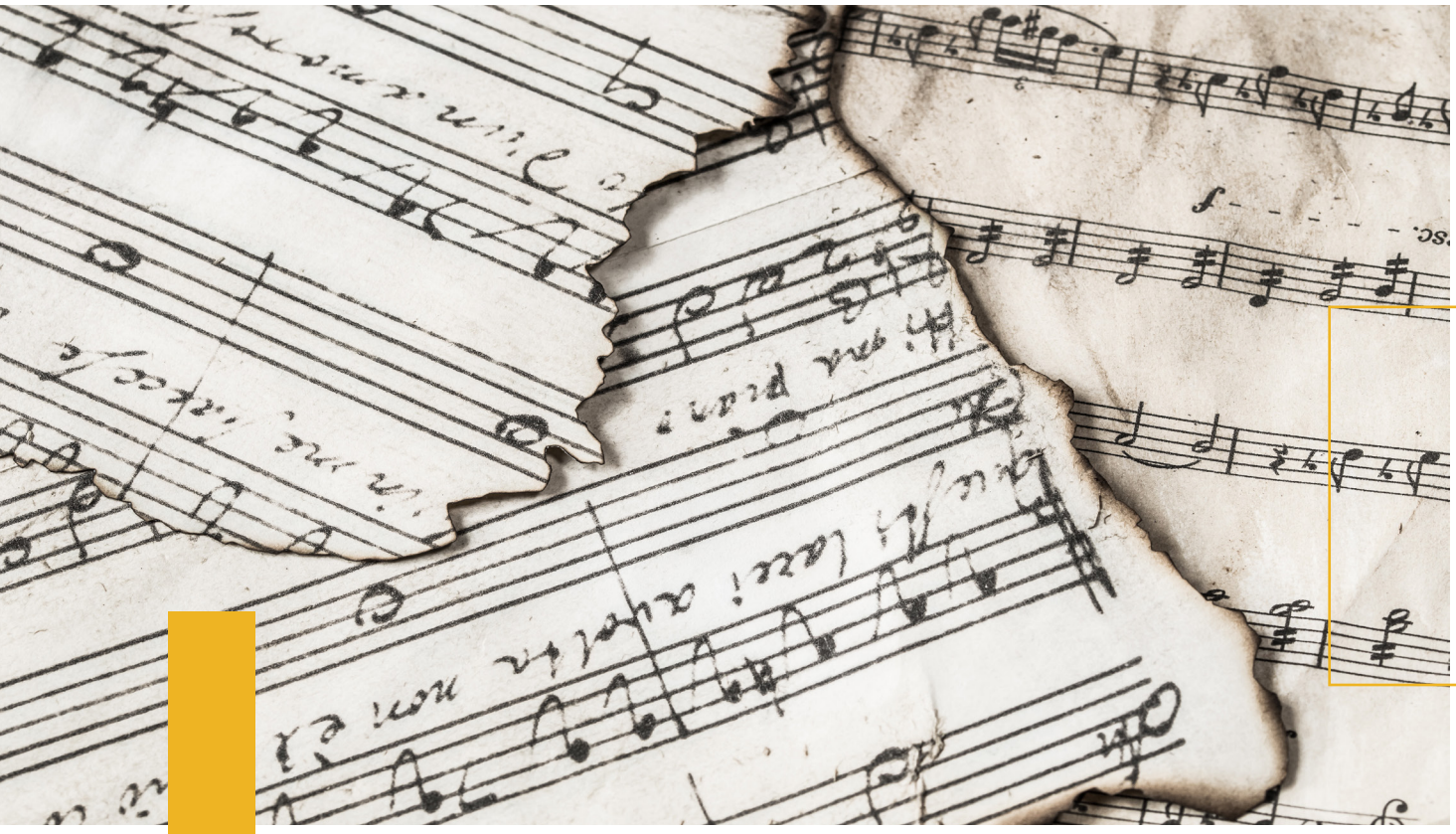
We are thrilled to share with you the third issue of Western Washington University's Behavioral Neuroscience student-led magazine, appropriately titled brainSTEM. Inside, you will find articles that epitomize our passions in neuroscience. Scientific literature can oftentimes be challenging to understand for those not in the field. Our goal was to create an easily digestible and enjoyable read for those that are interested in neuroscience but perhaps without the background. We could not have accomplished this issue without Dr. Jeff Grimm, Director of the Behavioral Neuroscience Program, and Andrea Swanson for their integral help in the creation of brainSTEM. Additionally, we express endless gratitude to our many professors and teachers that have supported us along the way in our academic careers. Cheers as we continue on the journey of being a lifelong learner. Thank you for reading, and we hope that you love it as much as we do.

All the best,
The brainSTEM authors and creators

Pictured left-to-right: Jack Jones, Michael Kihanya, Ella Gambell, Becca Marx, and Finn McGuinness.

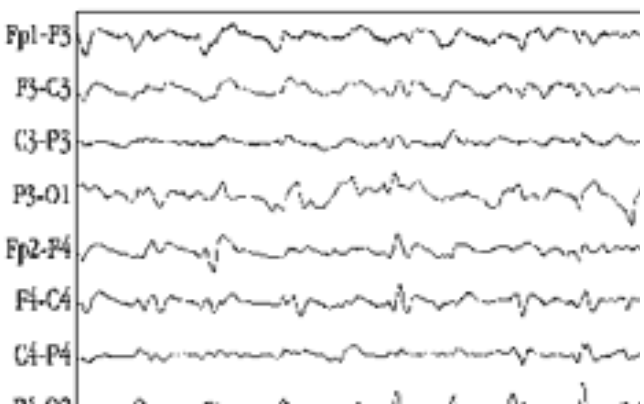
CONTENT

WWU Behavioral Neuroscience



"In all North American native cultures, when the newborn baby attends its first pow-wow, it hears the drum and is comforted, for the drum duplicates the beat of its mother's heart and is associated with warmth, life, sustenance, and security. The drumbeat is symbolic of Life itself. The drum is honored as a reflection of the heartbeat of Nature, of Earth, of mother, and of the heartbeat of the Indian peoples." - Kay Gardner from Sounding the Inner Landscape: Music as Medicine

Music scores our lives, and neuroscience gives us tools to define the amazing connection music has with the human experience. The feelings we get, the excitement, the community, the happiness, the sorrow, the melancholy are all results of chemical and electrical communication in our central and peripheral nervous system. The urge to move, to salsa, or moonwalk, to whip (or nae nae) are all results of these same systems. Our emotional and physical reactions to music are a byproduct of the collection of white matter and gray matter we call the brain.



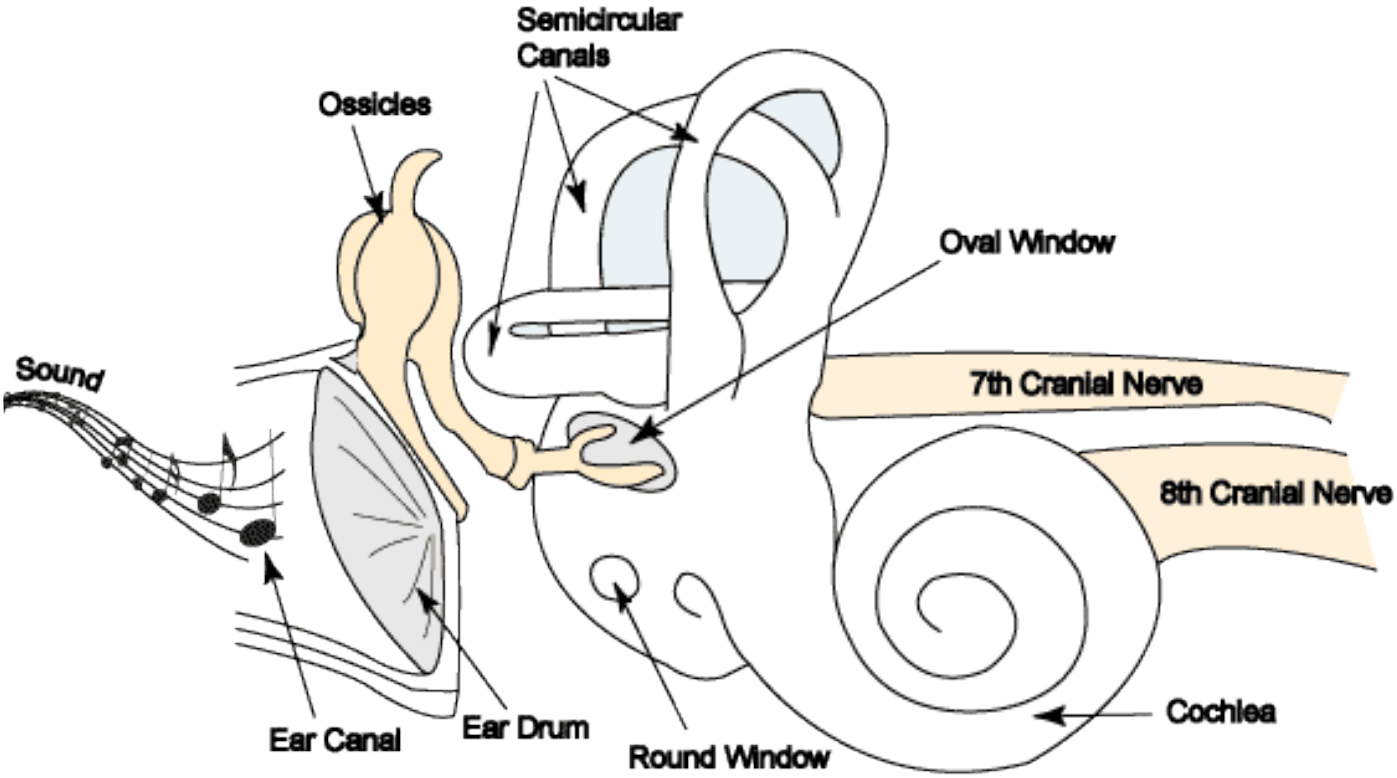
IMPLICATIONS OF THE "MOZART K448 EFFECT"

MICHAEL KIHANYA

Before we go any further, music must first be translated (or transduced) into a language the brain can understand.

The ear is a transducer. Similar to a microphone, the ear works by amplifying an acoustic signal then translating it into an electrical signal. Acoustic signal is the compression and rarefaction of air molecules [1]. Put another way, the back and forth motion of air creates sound waves. Suppose you are walking on the sidewalk and you hear a truck go by. You are hearing the movement of the air molecules the truck, its tires, and the engine have collided with. Your ear functions by converting these vibrations in the air into electrical signals recognizable by the brain.

Sound energy is gathered by the external, visible part of the ear and directed towards the eardrum. Your eardrum vibrates at the same rate as the air molecules moved by the truck do. This rate (also known as frequency or pitch) is then transferred to the inner ear by three small bones called the hammer, anvil, and stirrup – collectively known as the ossicles. Functioning like a lever, the ossicles send the same sound waves that vibrate the eardrum into the cochlea. This liquid-filled membrane is tonotopically organized; inside, hair cells (varying in length) react to sound waves of specified frequencies – ranging from 20 to 20,000 cycles per second (Hertz). These hair cells are so sensitive to frequency that they will electrically activate [2]. Known as action potentials, these electrical activations are the language of the brain. It is how neurons communicate.



The ear turns stimuli from the outside world into patterns of action potentials that our brain recognizes as sounds to be appreciated or experienced in some way or another.

The experience of listening to music is unique to each individual and can be difficult to describe in words. Music theory and psychology can attempt to quantify music, but we know the intricate, inexpressible feelings music brings up. Rather than basing any conclusions on our subjective musical experiences, this article is confined to quantitative methodologies and information.

Δ Brain

In the late 13th century, Peter of Abano was one of the many physicians using music in their work [3]. Notably, he utilized nose and treat disease. This idea – of using music as a healing agent – is not new. What is novel though, is the brain-imaging technology allowing us to "see" the brain in action.

Quon et al. use electroencephalogram (EEG) in their 2021 study published in Nature to examine the effect of music on a specific kind of brain activity (known as interictal epileptiform discharges, or IEDs) associated with treatment-resistant epilepsy [4]. IEDs "arise from the brief, synchronous firing of neural populations that are typically involved with epileptic networks". They serve as biomarkers, predicting the duration of seizures and cognitive impairments [5]. Without the ability to observe the brain in action it would not be possible to measure the effect of music on the brain with such temporal accuracy.

In Quon et al.'s study, two sonatas were played to subjects for either 15 seconds or 90 seconds. Results revealed that Mozart's Sonata for Two Pianos in D Major (K448), not Mozart's Piano Sonata in C Major (K545), resulted in two major changes in the brain. Firstly, K448 induced changes in brain activity to reduce seizure-like activity and secondly, increased frontal lobe theta power during transitions from prolonged musical segments. The reduction of seizure-like activity (i.e., IEDs) was significant only after at least 30 seconds of exposure to K448, emphasizing the importance of stimulus duration. An increase in theta power in the frontal lobe confirms past findings, "which demonstrated that pleasant music was as-

sociated with increased theta power" [6]. Both of these results glean insight into the mechanisms by which music changes electrical activity in the brain.

The findings above are significant, but the specificity of K448 is most profound. While other songs cannot decrease IEDs, K448 can. It follows, certain songs can be prescribed to address abnormal brain activity. That is to say, a specific song and all of its associated characteristics (tempo, melody, key) can address a specific neurological issue. Music can be designed and used clinically in conjunction with pharmacological or invasive therapies.

Before streaming services and grocery store jingles abundant, it could be argued our experience with music was, by default, therapy. The statistics, biology, psychology, and statistical significance of neuroscience answers the question, "Where's the proof?". It gives numbers, words, and structure to human experiences previously intangible. It legitimizes music as a therapeutic option.

Much remains unknown regarding the mechanisms of music, but this study provides the scientific community a stepping stone for further examination and analysis of non-pharmacological, non-invasive, musical interventions – particularly for epilepsy.

THE NEUROAESTHETICS OF MUSIC

ELLA GAMBELL

Close your eyes and imagine that you are listening to your favorite piece of music. What feelings arise in your body and mind? Perhaps you feel joy and the urge to get up and dance, or maybe you sense a melancholy nostalgia. Music can make us emote in infinite ways – the rhythms and beats resonate deep into our bones. These complex experiences are hard to define with quantitative science – they are often fleeting moments that cannot be put into words.

There is, however, a field of neuroscience dedicated to decoding the experience of art. Whether viewing a painting or listening to a music score, the area of neuroaesthetics investigates the underpinnings of the aesthetic experience [4]. Art can capture our attention and curiosity through bottom-up (sensory-driven) and top-down (cognitively driven) processes [4]. For example, envision that you are walking down a city street, hearing live music from a

few blocks away, and finding yourself walking towards the sounds. This is an example of bottom-up processing. Or perhaps you hear an old hip-hop song on the radio and find yourself listening intently to the lyrics, trying to find meaning in the story behind them. This would be an example of top-down processing.

As humans, we have our basic emotions, such as happiness, sadness, fear, and disgust. While music can certainly trigger these, the field of neuroaesthetics has focused research on three complex aesthetic emotions: awe, enjoyment, and nostalgia [4].

The feeling of awe is unique to aesthetics, meaning that it does not come from typical, casual listening. This emotion is rare and distinct for everyone, making it even more special. This is caused by beautiful music performed in the ideal acoustic setting that can leave you feeling like the sounds have permeated every cell in your body.

The enjoyment of music is the easiest to study, which is done by focusing on the chills we get while listening, such as goosebumps or flutters down the spine. People who score highly on openness to experience get more chills in response to music, which is mediated by how often they listen to and value music in their everyday lives [4].

A study by Salimpoor and colleagues [12] showed that chills are associated with dopamine release in two brain areas. These areas include the the nucleus accumbens – which releases dopamine in the ventral tegmental area, and the ventral striatum [4]. Dopamine is a neurotransmitter involved in many different processes like mood, movement, and motivation. The ventral striatum and nucleus accumbens are associated with reward, pleasure, and motivation for activities involved with survival and the transition to chronic drug use [4].

Neuroanatomy aside... the chills that we receive while listening to music are connected to the reward circuitry in our brains that drives us to seek out pleasurable experiences.

Before diving into music and nostalgia, lets talk about how music evokes emotions.

HOW DOES MUSIC EVOKE EMOTIONS?

In all cultures, sensory consonance and dissonance have been used to manipulate the aesthetic experience of music [4]. Dissonance is when two sounds are played in concert and is associated with the presence of pounding or roughness. This is usually an unpleasant experience for the listener and is associated with activity in brain regions such as the parahippocampal gyrus and amygdala. The former area is correlated with withdrawal behavior and the latter with negative emotions and salience.

Consonance, on the other hand, is considered the absence of dissonance. This feature is associated with soothing sounds, pleasantness and activation of the reward areas of the ventral striatum and the brain stem [4].

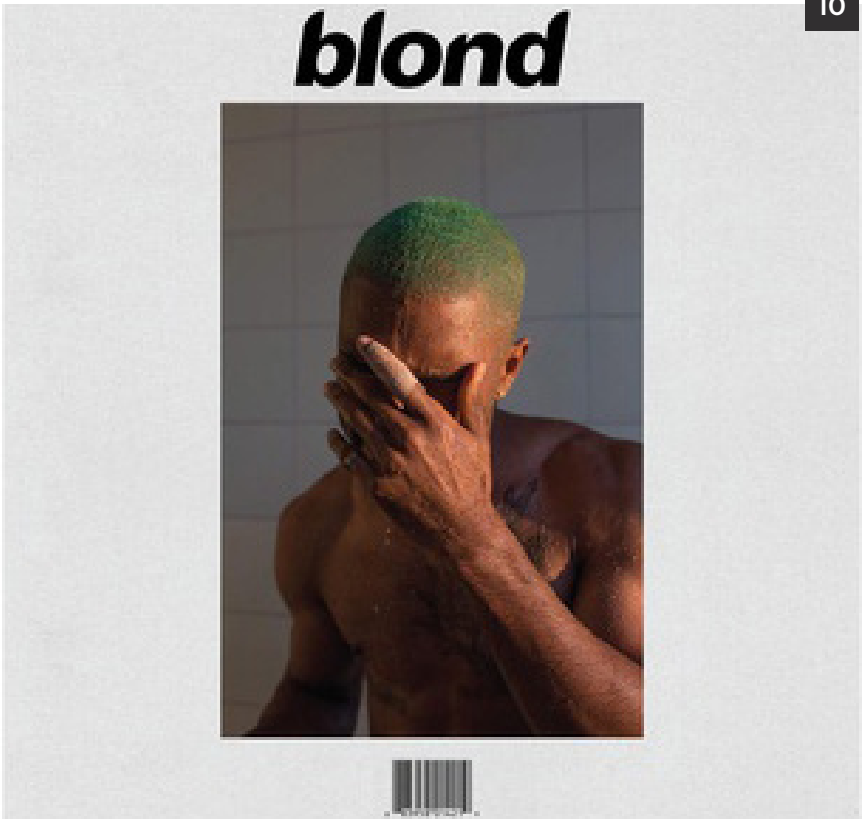
Another way music can induce an aesthetic experience is by imitation. In this case, through temporal structure and pitch, a song can exhibit characteristics similar to the behavioral expression of music [4]. For example, fast, higher-pitched

music can represent lighter emotions, while slower, heavier music can be expressive of sadness.

BRAIN CONNECTIVITY WHILE LISTENING

The default mode network (DMN) is a connectivity network in the brain with activation associated with unfocused thought and mind-wandering. Activation of the DMN is also negatively correlated with goal-directed tasks that involve introspection, self-referential ideas, empathy, and self-awareness [1].

Music listening is an activity associated with mind-wandering and unfocused thinking and could alter the activation/connectivity of the DMN. A study found that the activation of the DMN is most connected when listening to music that we like and to our favorite songs [13].



Mind-wandering is another term for daydreaming. People who enjoy listening to music often find that the journey of a song can send them into a deep cascade of free-flowing thoughts frequently accompanied by personal realizations.

Featured Albums

Left: Tame Impala - Innerspeaker (2011)
Listen with headphones and your eyes closed to feel chills and awe

Top right: Frank Ocean - Blonde (2016)
Slow, heart piercing tunes for getting into your feelings

Bottom right - Fleet Foxes Self Titled Album (2008)
Upbeat, woodsy tunes that make you feel like frolicking in the forest

MUSIC AND NOSTALGIA

How can listening to music make you feel like you are traveling back in time? Music evokes nostalgia, which is an emotional experience that accompanies autobiographical memories. Nostalgia is a complex emotion that can be positive and negative- often bittersweet. Evolutionarily, it is believed that nostalgia serves to counteract sadness and loneliness, perhaps by bringing us back to a time when we felt happy and comforted. Nostalgia may even have socially relevant benefits by increasing the feelings of connectedness to others and perceived social support [5].

A study used music-evoked autobiographical memories to explore nostalgia, investigating the differences between participants' relationships with the music and how prone they are to nostalgic experiences [4]. Researchers exposed participants to 15-second song samples from the Billboard Top-100 Pop, Hip Hop, and R&B lists on Apple's iTunes store. The songs for each participant were randomly selected from music released when they were aged 7-19 years. This study found that autobiographical salience is the most significant predictor of music-induced nostalgia [5]. That being said, music that is deeply entwined with your memories is more likely to take you back to the past than pop songs on the radio.

However, memories are not equally distributed across the lifespan. Autobiographical memory research has demonstrated that our most influential memories occur parallel to significant changes in ourselves and goals over time [9]. Our sense of self develops and changes throughout adolescence and into adulthood, a period of time research has called the "reminiscence bump" [9]. We experience things during this time that are self-defining and often linked to other memories, highly emotional and vivid. Emotional events get encoded into our

long-term memories, and pairing this with music is like providing a cue for those memories to be retrieved.

Gabriella, 22, a Temple University Advertising graduate, is an avid music listener and has spent the bulk of her adolescence and young adult life discovering new music in her free time. Gabriella states:

"I have made a monthly playlist for the past five years, pretty much without fail. Sometimes I'll go back and listen to them, and I can be fully transported back to the memories I made during that time, the feelings I was feeling, and the people I spent my time with. It's almost like having an auditory yearbook."

(Gabriella Foschini, personal communication, April 26th, 2022)

Neuroimaging studies have investigated the active brain regions during music-induced nostalgia [5]. Nostalgia revives emotional memories, activating our brains' limbic, paralimbic, and medial prefrontal areas. The limbic system is involved in processing emotions, motivation, memory, and learning. The medial prefrontal cortex is correlated with long-term memory.

When our emotions are strong, these feelings get stored into our memories. Through the lyrics, rhythms, and beats, music evokes our emotions with enough power for our brains to take a screenshot of the present moment for us to reminisce in the future.

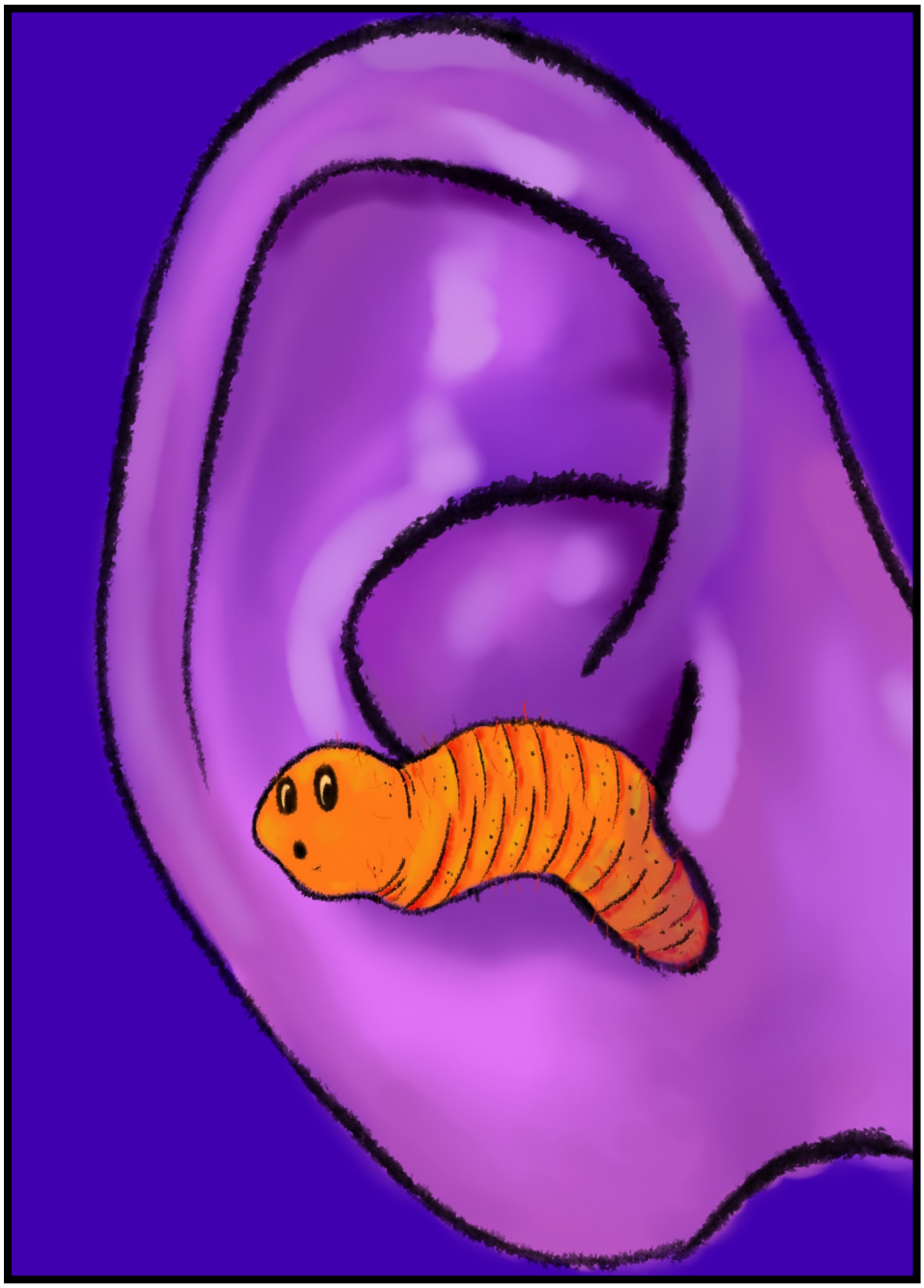
WHY WON'T THIS SONG GET OUT OF MY HEAD?

We all have experienced it before – a catchy tune seemingly living "rent-free" in our minds, manipulating our consciousness to sing it aloud without our awareness. This catchy tune has been coined as an "earworm," which can be a pleasant, unpleasant, or neutral experience for the person it dwells in.

What exactly are earworms? They are a form of auditory imagery where a song is "heard" in our heads and plays over time. The basis of these is more cognitive than environmental; they are usually not cued by things we hear outside of our minds. However, mind-wandering can cue it. So, if you find yourself drifting off into unfocused thought ... an ear worm might sneak into your brain!

Apparently, the frequency of this occurrence depends on the person. People with an active music interest and training are more likely to experience earworms [7].

Earworms, also called "sticky tunes," are triggered like involuntary recollections, often stuck in a playback loop. For those of us who experience earworms, we know all too well how these tunes can feel sticky in our brains, especially when they are songs that we are not particularly fond of – like an overplayed pop song from the radio. Researchers call the attempt to control earworms "ironic mental control," where trying to suppress the music makes it more accessible [3]. By checking to see if the earworm went away, we are actually cueing it to replay.

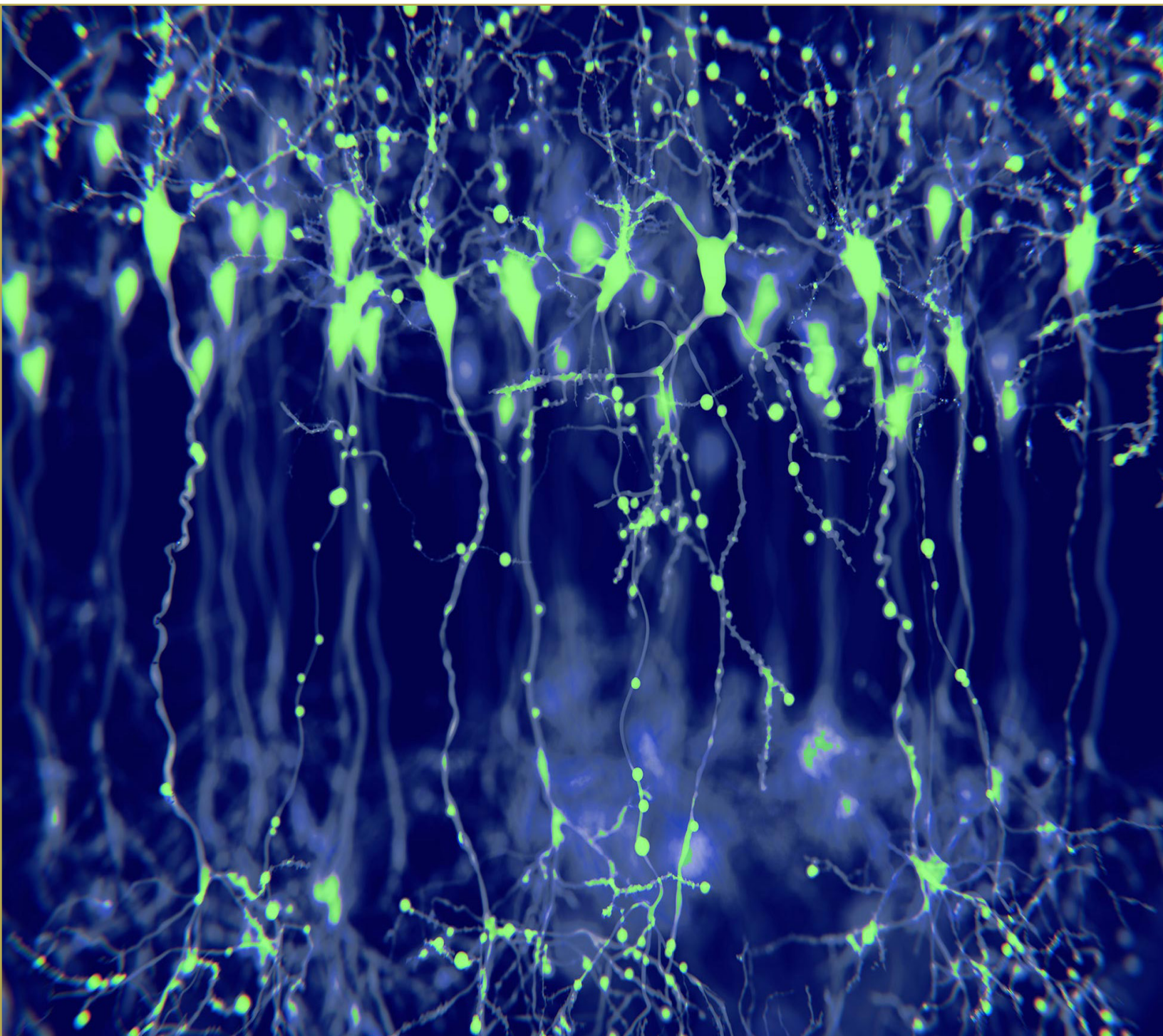


Dr. Ira Hyman from Western Washington University has decoded the why and when of earworm occurrences [6]. He and his research found a few basic requirements for an earworm to pop into awareness. The first is that the song will be typically well known and liked by the person and stored in long-term memory [6]. Next, these earworms, which he calls "intrusive songs," must regularly reflect environmental priming and cueing. For example, listening to that song or even hearing a word from the song can act as a cue. Finally, intrusive songs usually return when our brains have a low cognitive load, such as mind-wandering moments.

It is a uniquely human experience to feel a shiver down the spine in response to another person's art. To feel the rhythms and tones of music permeate every cell layer in the body, resonating deep into one's bones, leaving a feeling of transcendence and awe. The field of neuroaesthetics seeks to quantize and define just how our brain translates art into these sensations.

Listening to music gives us the power to time travel into the past, experience the person we were, and the feelings we felt when we first heard a song. Music evokes nostalgia, and what you listen to during self-defining moments will have a lasting impact on your memory.

Despite the occasional earworm, it's pretty magical how music can be the final puzzle piece in defining a moment.



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Side effects may include feelings of anxiety, nausea, lack of coordination, dry mouth, loss of appetite, bruxism, distortions in the perception of time, ego-dissolution, or mind-altering hallucinations. Do not consume alcohol or operate heavy machinery while under the influence of this drug.

PSYCHEDELICS AS ANTI-INFLAMMATORIES

FINN MCGUINNESS

Classical psychedelics are a subset of hallucinogenic drugs that exert their effects on the mind primarily through binding to the 5-HT2A receptor to produce states of consciousness among the loftiest realms of thought attainable. For this reason, experts who research these drugs have debated endlessly as to what nomenclature best describes their effects.[1]

Since their discovery, psychedelic drugs have fascinated researchers with their profound effects on perception and cognition. This intrigue is reflected in the language that has been used to classify them: phantastica, phanerothyme, and psychedelic, with the intended meanings of "imaginary appearance," "visible soul," and "mind-manifesting," respectively, all speak to the hallucinatory or transcendent experiences that these molecules can induce.[2,3,4] Similarly, Ruck et al. proposed the term entheogen, with the intended meaning of "creating the divine within," which has become increasingly popular in the media and lay community.[5] None of these terms perfectly capture the subjective effects of 5-HT2A receptor agonists (rightly so, it is difficult to formulate language to describe experiences that border on the ineffable), but "psychedelic" has remained the most widely used.

These experiences are often rated by users as being among the most transformative events of their lives.[6] Therefore, it's to be expected that most clinical psychiatric research surrounding these drugs has focused on the ability of the altered states of consciousness they produce to treat disorders such as depression, end-of-life anxiety, or post-traumatic stress disorder (PTSD), in conjunction with psychotherapy. However, recent preclinical research suggests that the therapeutic value of psychedelics might extend beyond the phenomenal effects they produce in the mind.

Namely, it's been discovered that some 5-HT2A receptor agonists exhibit extremely potent and long-lasting anti-inflammatory effects at doses below those that have obvious effects on behavior. Much of this research has been conducted by Dr. Charles D. Nichols, son of Dr. David E. Nichols, one of the most prolific psychedelic researchers in the field. The younger Nichols is an esteemed pharmacologist in his own right, and his research is pushing the boundaries of psychedelic medicine.

In 2008, members of the Nichols lab discovered that (R)-DOI, a 5-HT2A agonist with subjective effects similar to LSD, has super potent capabilities to repress tumor necrosis factor alpha (TNF-alpha) induced inflammation in a rat model of asthma.[7] For perspective, the IC50 value, the half maximal dose for a drug at inhibiting a given biological function, is in the micromolar range for nonsteroidal anti-inflammatory (NSAID) drugs, like ibuprofen, and in the nanomolar range for steroidal anti-inflammatory drugs, such as corticosteroids.[8] Incredibly, the IC50 value for (R)-DOI was found to be in the low picomolar range, ~300-fold more potent than the current, highly effective anti-inflammatory drugs.[7] As noted by the researchers, aside from a few natural toxins, such as botulinum toxin, no current drugs have a comparable potency.[7]

The anti-inflammatory capabilities of other psychedelic drugs were also examined, and although they exhibited anti-inflammatory properties, they did not possess the super potency exhibited by (R)-DOI. This is surprising, since many of these molecules have significant structural and behavioral similarities.[7] One possible explanation for this observation could be due to what's known as functional selectivity or biased agonism, a phenomenon where different drugs induce different conformational changes to the same receptor, which results in unique intracellular signaling cascades. From this perspective, the serotonin neurotransmitter stabilizes the receptor in a conformation that activates intracellular signaling pathways that are proinflammatory, while psychedelics stabilize a conformation in the receptor that is associated with an anti-inflammatory signaling pathway. [7]

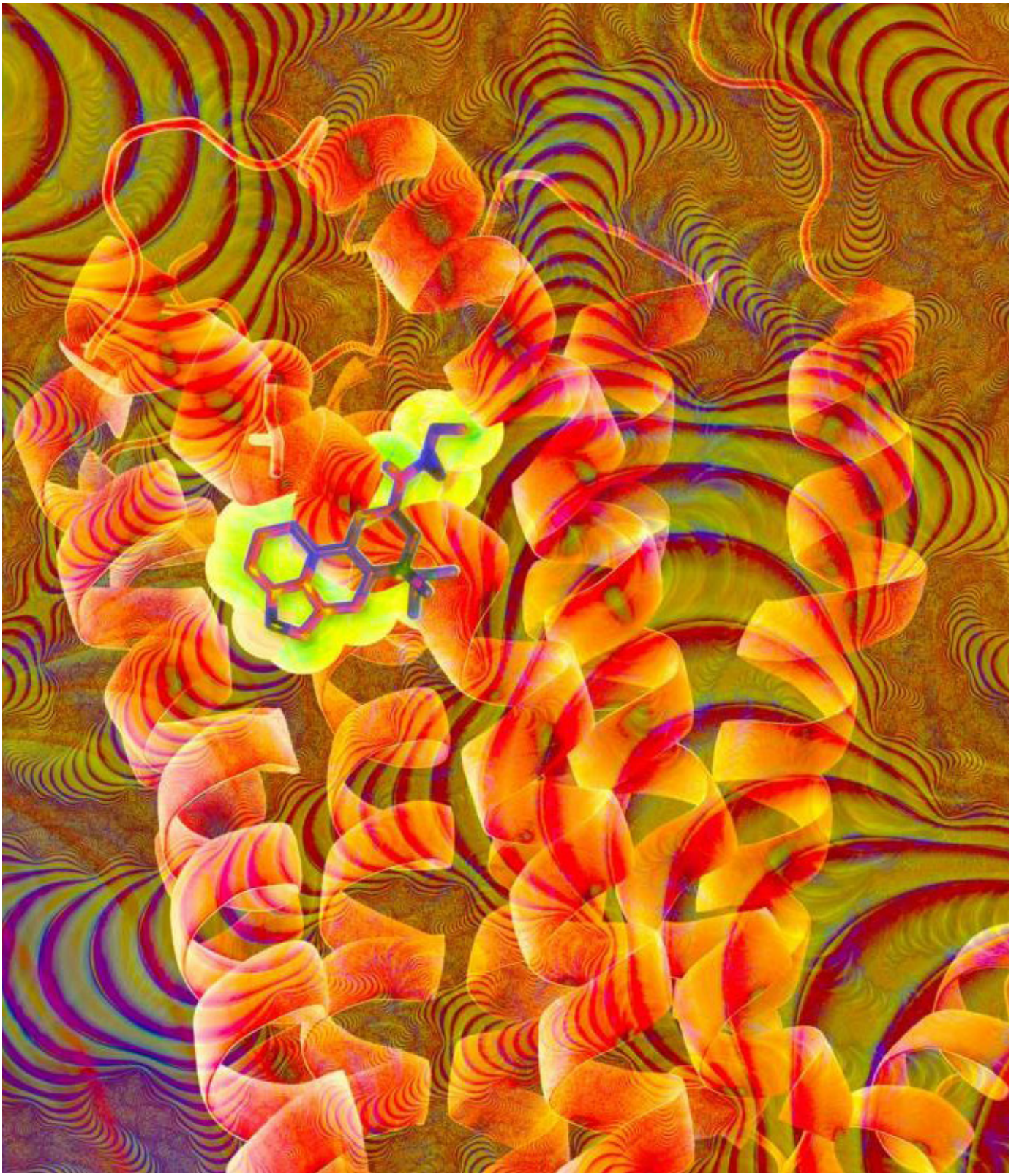
Nichols explored the role that functional selectivity plays in the 5-HT2A agonist-mediated anti-inflammatory response further by probing the structure activity relationship (SAR) between psychedelic compounds and their ability to reduce inflammation. Analyzing the relationship between the chemical structure of a drug and its biological activity allows researchers to identify the functional group or structural motif that is responsible for causing a physiological or behavioral effect. Starting with (R)-DOI, their prototypical anti-inflammatory agent, Nichols made numerous modifications to its structure and evaluated the effect it had on the new compound's ability to reduce inflammation. Some modifications were not well tolerated, creating drugs that were less effective, while some modifications resulted in compounds that retained full efficacy at reducing inflammation. [9]

Curiously, these less effective compounds are known to be potently psychedelic (with some even being sold as designer drugs). This observation lends credence to the notion that a certain structural feature present in (R)-DOI must be maintained for psychedelics to be antiinflammatory. By the same token, there is a structural feature shared among these compounds that must be present to produce the psychedelic experience.[9]

Though psychedelics have been found to be effective at treating mental illnesses in some cases, the mechanism by which this improvement occurs is not fully understood. However, since many psychiatric illnesses have an inflammatory component, it seems plausible that some of the benefits to mental health associated with psychedelics is due to their antiinflammatory properties.[10]

These findings are significant in two crucial ways: firstly, these drugs could represent the building blocks for the next generation of antiinflammatory drugs; secondly, but perhaps of even greater importance, this discussion exemplifies how prohibitionist drug policy in the United States limits and influences neuroscience research.

To be more specific, illegal drugs in the United States are organized into "schedules" according to criteria laid out and evaluated by the drug enforcement agency (DEA). When scheduling a drug, the DEA considers its abuse liability, the harm it poses to the user, and whether or not it has any medical uses. Drugs with a high abuse liability, a high risk profile, and no known medical uses are placed in schedule I, the most prohibitive category. [11] In reality, however, many of these drugs were placed in schedule I before their medical efficacy (or abuse potential and risk profile, for that matter) was determined. Still, even once a scheduled drug has been shown to have medical efficacy, there is no sensible method of recategorizing a drug into a less restrictive schedule. The extent to which this strategy is problematic is unfortunately beyond the scope of this article (see Drug Policy and Limitations in Neuroscience in brainSTEM issue no. 2), but suffice to say there are a number of illegal and stigmatized drugs that have therapeutic efficacy, which we likely have only begun to scratch the surface of.



LSD IN COMPLEX WITH THE SEROTONIN RECEPTOR

Created by Annie Spikes

"We all suffer under a white supremist, capitalistic, and patriarchal society."

Epigenetics and Generational Trauma: It Didn't Start with You

BECCA MARX

Trauma can be acute, chronic, or complex and is typically characterized as an emotional response to a highly stressful event. Stress is an environmental factor that has great power in shaping our lives and the lives of our offspring for generations to come. This is because stress responses can be taught and absorbed by young minds during early development. Stress responses can even become a part of a culture. If we are taught that we are unsafe in our environment, we will act accordingly and live in survival mode- sometimes even when the danger is long gone.

Unsafe and traumatizing environments affect people in different ways. While we all suffer under a white supremist, capitalistic, and patriarchal society, some marginalized groups are unjustly forced to bear the burden of our ancestors more than others. Unsafe and traumatizing environments can affect people in the moment and the future. Genocide, enslavement, and forced internment, to name a few examples, likely lead to epigenetic changes that may be trans-generational. Reparations are grievously necessary but vastly shortcoming. Peoples' genetics have been altered due to their environment through no choice of their own- this field of study is known as epigenetics.

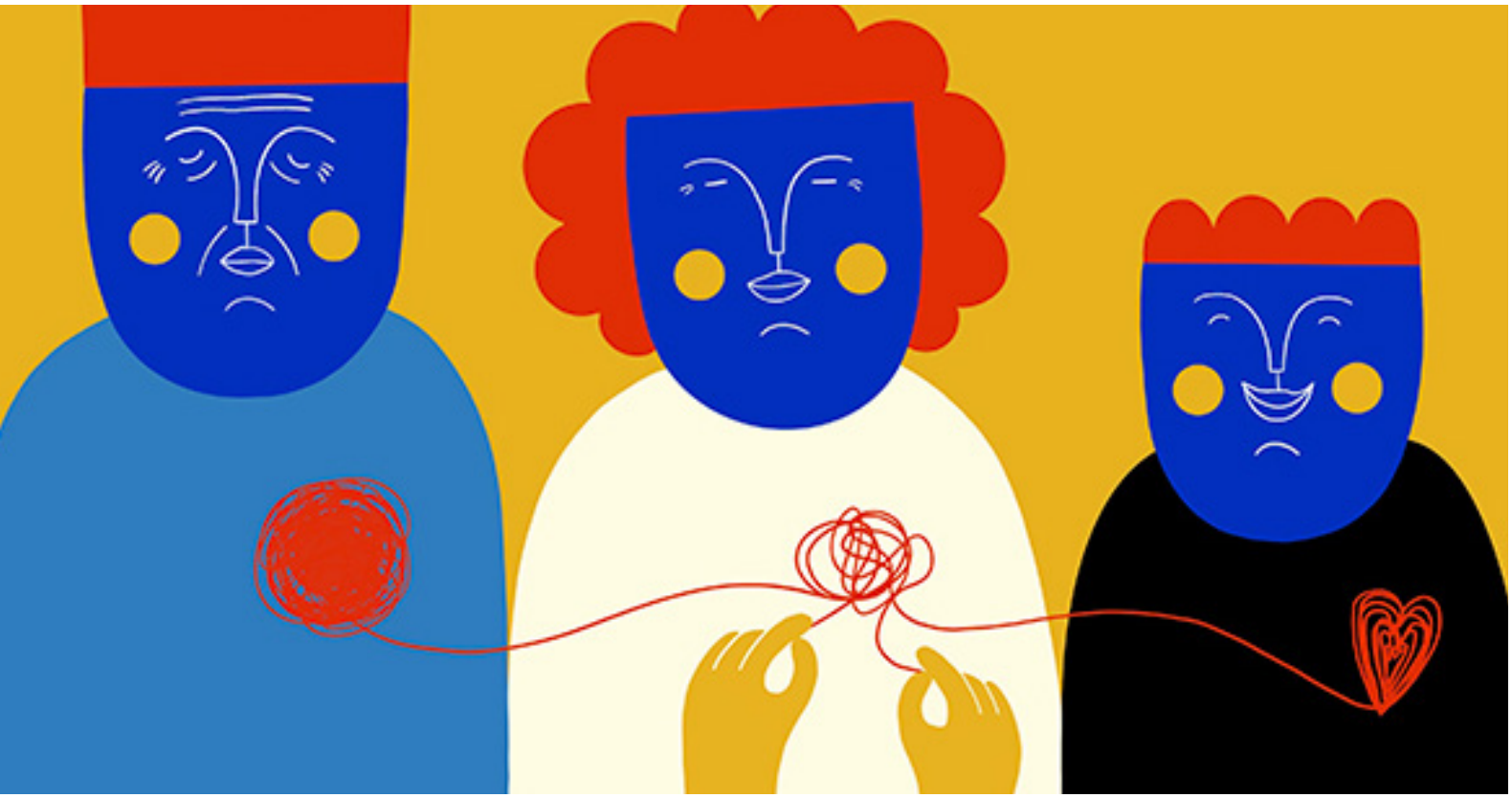
REPARATIONS NECESSARY SHORTCOMING.

ARE GRIEVOUSLY BUT VASTLY

...ONCE WE ARE COGNISANT OF OUR WOUNDING WE MUST DO OUR PART AND TRY TO BREAK THE CYCLE BEST WE CAN.

Epigenetics is the study of how our external environment and our way of interacting with the world around us alter our genetics. Stress is a major environmental factor that has the power to alter our genetics. Gene alterations can be inherited by our children either through social, intrauterine, or gametic pathways and give them the same stress response that we developed in order to protect ourselves the way our brain and body deemed fit[1]. This is known as generational trauma: the inherited stress responses that our ancestors developed in order to protect themselves from the dangers at the time.

Generational trauma can present itself in many ways. It can be an aversion to physical touch, hypervigilance, depression, a scarcity mindset, mistrust, abusive behaviors... the list goes on[1]. We are taught by our caregivers how to interact with the world and the people in it. However, some of our ways of interacting with the world are genetic, such as depression with a 37% inheritance rate[2]. A 37% inheritance rate means that 37% of people that have a parent with depression also have depression themselves due to no obvious reason other than genetics. Despite this, once we are cognisant of our wounding we must do our part and try to break the cycle best we can. A simpler example of breaking the cycle of stress and trauma using physical touch is demonstrated using a rat model on the following page.



Rats that perform licking, grooming, and arched-back nursing (LG/ABN) have been shown to result in rat pups that are more resilient to stress and show less anxiety-like behaviors[3]. This improved stress response is passed down to that rat's babies, even if it was not born to an LG/ABN mother but was nursed like that in infancy. A rat mother that arches her back while nursing allows pups to have an easier time accessing milk while licking/grooming behaviors provide tactile stimulation. The tactile stimulation caused by licking and grooming from LG/ABN mothers increases serotonin levels which in turn leads to a signaling cascade that alters the expression of the glucocorticoid receptor (GR).

The GR gene is responsible for modulating stress responses. When GR is at a normal level, stress responses are adaptive and appropriate, and when the gene for GR is dysfunctional, there are fewer glucocorticoid receptors that then result in an overactive stress response. A good mother that licks and grooms her young deletes harmful methyl groups from the DNA in the promoter region of GR, which in turn upregulates the GR gene in the pups. When the GR gene is methylated and a pup didn't receive LG/ABN, the GR gene can no longer function to lessen the pup's stress response and we see a greater reaction to fearful stimuli with greater anxiety-like behaviors and a less adaptive response to stress. This data shows how early age environmental factors can alter our genes and be passed down for generations. Therefore, good rat mothers are taught and shaped by their environment, not born with good maternal instincts.

Research serves as a tool to explore more about ourselves and ultimately can give us the tools to heal, should we choose to use them.

WHILE IT DIDN'T START WITH YOU, YOU HAVE THE POWER TO LET THE CYCLE END.

While this is a rodent model of epigenetics, it still exemplifies the power of "good" parenting and how stress can alter our genetics and lineage for generations to come. The data derived from rat pups also shines a light on the importance of affectionate behaviors and tactile stimulation on development as it applies to humans- babies thrive with loving human touch and suffer without it, and have even been recorded to perish without adequate affection and mechanosensory stimulation[4]. Likewise, adult humans thrive when surrounded by an abundance of loving tactile stimulation, even in the presence of stress, and suffer in its absence just the same.

We know stress can have disastrous effects on the body- when traumatic stress continues to proliferate in someone's life, they may reach a diagnosis of post-traumatic stress disorder (PTSD). Individuals may be more susceptible to acquire PTSD through genetic predisposition due to an irregular expression of innate immunity[5]. The irregularities in innate immunity can then lead to abnormal GR function, potentially leading to PTSD. It's easy to see then how traumatic events and environments can shape our reality and mental health. These stress responses can then go on to alter our genetic blueprint and be passed down to offspring, as seen in the modulation of the GR gene from LG/ABN with a rat model.

There is much more to discover in regards to epigenetics and generational trauma. Research serves as a tool to explore more about ourselves and ultimately can give us the tools to heal, should we choose to use them. While it didn't start with you, you have the power to let the cycle end.

"Be informed, then choose."

- Alexander Shulgin

NO MORE DRUG WAR

Students for Sensible Drug Policy is an international, youth-led organization advocating for the abolition of the War on Drugs in favor of more compassionate, science-based policies. We bring young people of all political and ideological orientations together to have honest conversations about drugs and drug policy. We create change by providing a platform where members can interact with our local representatives, provide drug education to the community, and promote harm reduction strategies.

If you care about neuroscience you should care about drug policy!

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NERDS

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Neuroscience in Business (with Kara Goldhamer and David Ogle)

MICHAEL KIHANYA

Welcome to a conversation about neuroscience in business. As the field of neuroscience expands into traditionally "unscientific" disciplines – such as economics, political science, and even theology – it is important to explore how the ever-expanding database of mechanisms describing how we think, learn, and experience is implemented outside the world of neuroscience.

I had the great privilege of connecting with two business folk who come to the conversation with different backgrounds. Despite their occupational differences, Kara Goldhamer and David Ogle share an authentic fascination with, and appreciation for, neuroscience.

With Kara Goldhamer

Michael: Can you tell us who you are and what you do?

Kara: Kara Goldhamer. And I am, for all intents and purposes, a strategic customer experience and user experience researcher and strategist, but that's my profession. By education, I'm an information scientist and anthropologist, and have a business degree.

Michael: You mentioned when we talked about your four areas of expertise, am I getting that right?

Kara: Yeah. When I look at what I do professionally, I feel like I have four pathways of skill that have kind of brought me to this work. For sure anthropology. Business, information science and then, within information science, human and computer interaction, which is where a lot of my neuro training comes from.

> WHAT IS WORKING ON A REAL, CHEMICAL LEVEL TO ENGAGE PEOPLE IN A

Michael: The computer human interaction I know is where the neuroscience is focused. So I'd love for you to go into a little bit more about what that looks like for you and how that plays a role in your work.
Kara: Well, let me start from the beginning. It was the early 2000's when I started human and computer interaction. When we talk about neurobiology and information, it is a totally different world. There was still a lot of smoke and mirrors, but there were also a lot of really exciting things. Most of it was theoretical, but what was exciting at that time is that they were starting to be able to MRI the brain while it was active. They were starting to do different studies, both on humans and animals, but they could actually start seeing ***how***. As an information scientist, I was more looking at design and interfaces and kind of how it worked with the brain. But at that time, a lot of it was a lot more qual research, right. They would observe and kind of see. Fast forward to now, a lot of what I learned

was proven and disproven. It is incredible how mature brain science has become intime, a lot of it was a lot more qual research, right. They would observe and see what happened. Fast forward to now, a lot of what I learned was proven and disproven. It is incredible how mature brain science has become in 20 years both from a biological understanding and with regard to applicable research from a medical perspective.
Michael: So, how does this come into play in your work?
Kara: I'm building experiences, so most commonly we think of web delivered interfaces when we think of user experience. But I'm also developing or supporting the development of what we call customer experience. So within businesses, where and how people are engaging. There's a lot of things that I use from neuro learning. What motivates humans? What catches humans' interest? What is working on a real, chemical level to engage people in these experiences – be them an interface, a product, or a service?

I know the kind of things, in general, when we think of that sort of reptilian brain or emotional brain. I would actually say that sometimes I use it for evil, right. I just know to not get crazy on the design because these three things the human brain and the human emotional wants. It's always a reward system. It's not necessarily what might outwardly make us feel good, but it's what makes the brain engaged. That can be anything from how we organize information to how we put reward bread crumbs along the way. Are we making the user's experience easy or hard? The human brain always wants things to be easy. When we are building experiences, if we make them too hard, it causes friction. When there is friction, particularly in a for-profit company, you may lose a customer.

Michael: You mentioned the development of neuroscience. Do you try to keep up with the constant developments/new research coming out?

Kara: Yes! I have to do a lot of reading these days when I truly want to think about behavioral engagement and brain engagement because of what I originally said. I love biology and science, so I will dig into the hard stuff. But a lot of times what I need is what brain researchers have done and then distilled down into best practices. The other way I use neuroscience is I tend to be, at this point in my career, an educator. I really enjoy training others and building teams. I find the environments I'm in tend to be business-focused. They tend to be people from all different backgrounds, not often from a science background.

I find myself using neurobiology to train other people (particularly designers) to help develop empathy skills. As an information scientist, I think, "you can make this experience or this interface look good, but if we're not organized it doesn't matter". The human brain really likes organization. I often will use the example of how grocery stores are organized. It is a very organized system that works with our brain because of learned experience. You can imagine if you went into a grocery store and all of a sudden the vegetables were in the middle and the meats and tofu and cheeses were on the shelf somewhere. It would create total friction for your brain. You might even be like, screw it, "I'm out of here" because your brain likes routine so much. That's something directly out of neuroscience. That's an applied principle that we as experienced strategists use.

Michael: There's the design/reducing friction aspect in user experiences and training.

Kara: Yeah. The key is I'm using real applied principles. Personally, I can put the scientist hat on, cause I freaking love that stuff. But as a practitioner and professional, I ask, "What can I pull from neuroscience learning to make what I deliver better? Whether it's product strategy, a service, an interface, or if it's training".

With David Ogle

Michael: Could you speak to your background? Why is neuroscience such an integral part of your work?

David: I have always been quite interested in the thinking behind how and why we do things, which naturally connected me to the world of leadership development. Thinking about leadership theory, the impact and role of a leader. I love the concept of who someone is in a group and seeing the impact one leader can have on a team: both good and bad.

This led me to want to get deeper to the kind of scientific parallel to philosophy which is, really, neuroscience. The first neuroscientists were philosophers. Rene Descartes is a great example. He made some of the first models of the brain and he is a famous French philosopher.

When I did my master's in neuroscience there was a particular focus on insight and resilience. Both of these translate to the business I'm in which is creating the conditions for leaders to have better and more intentional insights that ultimately help leaders make better decisions.

Michael: Could you describe what it is you do now?

David: I bring a social neuroscience approach to coaching for business leaders and professional athletes. I coach through examining the relationship between the processes of one's mind, their actions, and their goals. Much of this relates to generating insights (discoveries, changes in perception) for leaders making difficult decisions.

Michael: How would you explain the role neuroscience plays in your work?

David: Think from a linguistic standpoint what metaphor does for us as humans. It allows me to create a visual representation of a concept that's often hard for me to articulate in and of itself. And therefore a metaphor allows me to convey meaning in a really clear and powerful way.

This challenge is like standing on the sidelines of a sports game rather than being on the field. That's a metaphor, right. And we constantly use metaphors. So, what I think neuroscience applied in the business context really helps with is that it ends up being a bit of a metaphor in and of itself. It's a very literal metaphor, but say I'm working with a manager and they're frustrated with someone on their team who isn't performing. It can be really complicated to explain why they aren't doing their job. Then we start talking about perspective taking and the science of what might be going on in their brain right now. Could they be triggered from a social safety standpoint? Is it status? Is it certainty? Is it autonomy? By using some of the frameworks of how the brain evaluates threats or rewards it allows them (that leader) to identify better language. They start to understand, "oh yeah, it's status for them". That's why they're taking these actions. Leaders can ascribe some meaning where they couldn't before.

It also makes it less personal. The moment we start talking about, oh, the brain is doing this, it's kind of like talking about my computer. My computer keeps giving me an error message. Okay. Let's talk about why there's an error message. For leaders, it can be impossible to separate our emotions from the decisions we have to make, and yet we have to make decisions. How do I at least reconcile with some awareness of the emotions that I have and label them. So, when I'm making that decision, I am understanding the whole spectrum of my experience of it.

Michael: The emotions being your brain. Right. And then awareness of that and then awareness of your behavior follows. And then changes can come here.

David: Think of cognitive behavioral therapy as a practice. One of its fundamental principles is: what's the stimulus? What are your beliefs? What are your actions? What are the schemas that are influencing it?

The CBT therapist will go through and explore with someone which then helps break it out and see the nuance and the distinctions, rather than one overwhelming experience. We'll take that model and apply it to a business context.

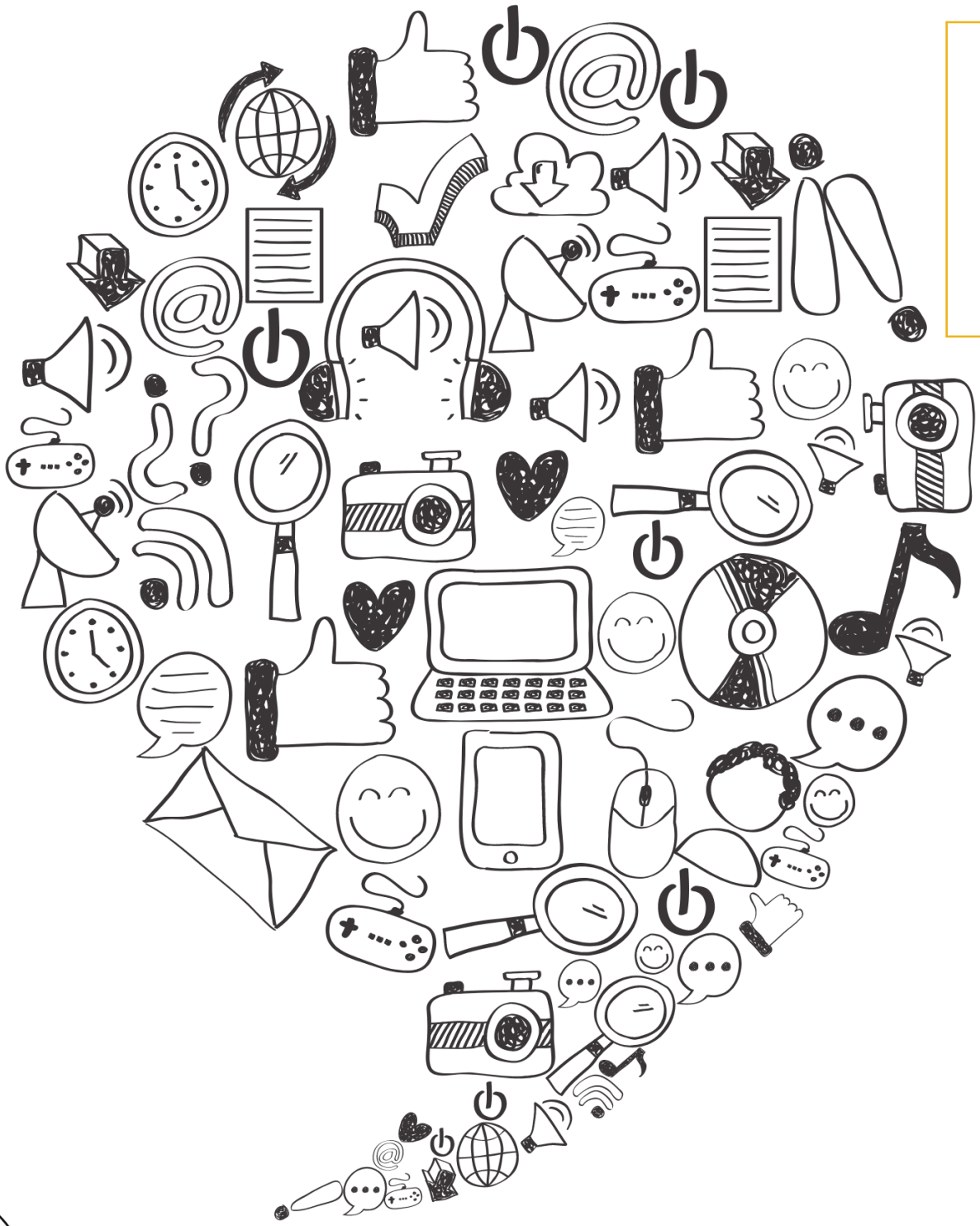
Leaders need that. They're making big decisions. They're making hard decisions that are complex and lack certainty. I think that the challenge of business is: "I have to make decisions that I am certain will create great business results, but nothing is certain". It's something that has been taught to us very definitively in the last two years. We can have a great business plan and then a global pandemic hits. Rather than trying to find certainty, having clarity with the data I am basing my decision on then making the decision. As the data changes, I can change my decision. It breaks it down for folks.

Michael: You help leaders break down the emotional complexity that comes with making decisions.

David: Yeah, exactly.

Michael: Thanks for taking the time to talk!

David: Of course!



THE TRICK IS ENGAGEMENT: SOCIAL MEDIA AND ITS EXPLOITATION OF HUMAN ATTENTIONAL SYSTEMS

JACK JONES

In our technologically integrated, late-stage capitalistic society, limitless information and entertainment are in our immediate reach and human attention has become an extracted economic resource. Recognizing the consequences of exploitative practices, advocates, such as Tristan Harris, are working to spread awareness. Harris has worked as a design ethicist at Google, taught Stanford's persuasive technology course, helped produce The Social Dilemma, and is the founder and co-president of the Center for Humane Technology, an organization committed to educating and advocating for humane technological policy and practices. As a child, Tristan practiced magic. He elaborates in a podcast interview that what fascinated him about magic was how the direction and misdirection of attention could effectively produce the illusion of magic. As social media has become seemingly universal, we have seen it, like magic, direct billions of users' attention towards screens. Demonstrated in Tristan's documentary, we are beginning to understand the neuroscience behind exploiting the limits of the human attentional systems as well as some of the adverse effects.

Young Tristan Harris prefroms magic

Human attention has its own economy: the attention economy. This attention economy has helped spur the growth of one of the largest extractive industries of our generation. Social media platforms, now closer than ever with smartphones being near-universal, are the latest technological manifestation of this industry. They capture large parts of users' days, directing their attention to their screens for hours at a time. Most readers will have had personal experience with the hours of endless "doom scrolling" associated with platforms such as Twitter, Instagram, Facebook, and Tik-Tok. Once under the guise of staying connected, we now see social media as one of the largest attention sinks of our modern society.

Our attentional systems evolved to promote survival. Our innate need to connect with others, live in social contexts, and concentrate, requires us to filter and engage with relevant stimuli appropriately. Neuroscience and neuropsychology present three main attentional systems, integrated into the attention system theory, which contribute to our ability to focus selectively [1,4,5]. These three networks include the alerting network, the orienting network, and the executive network, and they have evolved together to select information critical for efficiency and survival.

Life Without Smartphones

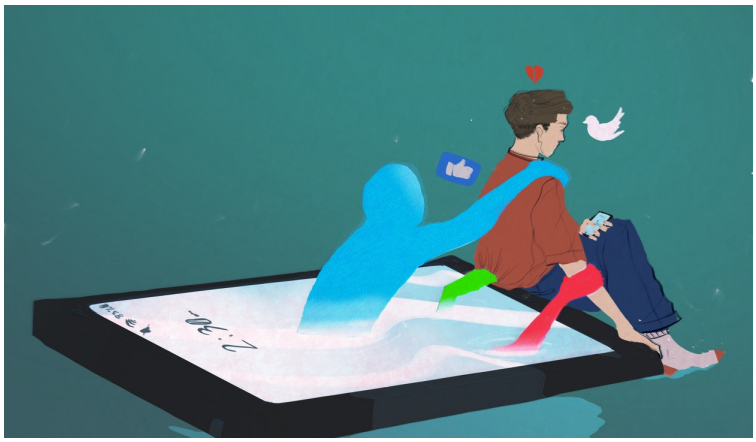
Eric Pickersgill - 2015

The alerting network involves changes in our internal state, preparing us to process stimuli, similar to vigilance or alertness [1,4,5]. As humans, cues in our suroundings become paired with physiological responses to prepare us to interact and perform in our environment. A cracking branch alerts our sympathetic nervous system, preparing us to fight, flight, or freeze. The right frontal and parietal cortices as well as activation of the locus coeruleus, a primary source of the neurotransmitter norepinephrine, are critical in the alerting network [1,5,6]. Together these brain regions facilitate a chemically induced shift in our physiological state to ensure that we interact with relevant stimuli to the best of our ability.

The orienting network helps to prioritize sensory input from a selection of information in order for us to stay attentive [1,4,5]. This network is found mainly in the superior parietal lobe, the superior temporoparietal junction, the superior colliculus, and the frontal ocular fields [1,5,6]. The neurotransmitter acetylcholine plays a critical role in the neuromodulation of this attention network. This network helps discriminate which stimuli are relevant for the focus of our attention.

Finally, a third integrated system is termed the executive network [1,4,5]. The executive network helps control attention through complex mental operations such as valuing stimuli and monitoring and focusing attention. Activity in the insula, the anterior cingulate cortex, as well as the lateral ventral prefrontal cortex, are critical for high level cognitive control and have been implicated in this executive network. Dopamine, a crucial neuromodulator that plays a role in motivational action and behavior, is a predominant player in influencing the activity of these regions.

Top-down and bottom-up processing mechanisms are present in all of these attention networks. Top-down processing produces higher neuronal activation when stimuli are relevant to goals, with a consequential increase in attention. Bottom-up processing attenuates attention when stimuli are repetitive but heightens attention to stimuli that are novel, intense, and infrequent [1]. These processing mechanisms are important for global network efficiency and can be utilized to take advantage of our attentional systems.



Social media appears to be magical in that it directs user's attention to platforms for hours a day with seemingly little diminishment in attention. Paired with an ever-present smartphone, designers have found ways to take advantage of the limits of these attentional systems, facilitating an exploitive approach to consumer engagement with their platforms. Beginning with the initial interest, we see the notification as a stimulus that immediately captures our exogenous attention, an involuntary attentional shift instigated by external stimuli. This is done by engaging the altering network which leads to changes in our neurophysiological state that prepare us to process environmental input [1,5,6]. The notification stimuli also employs the orienting and executive networks which select the notification stimuli, ascribe its value, and prioritize the action of responding to it [1]. This higher-level processing involves neural networks relating to motivation, memory, and learning to modulate motivational behavior surrounding stimulus [1,6]. Cycles of rewarding engagement condition the functional connectivity of these networks to respond in impulsive and habitual ways toward environmental cues, such as notifications [1]. This is demonstrated by the habituated glance at and internal attentional shift toward our phone when we register a notification.

It is hard to not shift our attention to notifications because our attentional systems are also mediated by our salience network [1,2,3]. Salience, the quality of being relevant and noticeable, is attributed to stimuli by the anterior insula and cingulate cortex [1]. Notifications, through top-down processing, become behaviorally and socially significant by being paired with rewards such as social validation, inclusion, self-image, and recognition. Therefore, notifications carry extreme salience in our evolutionary conserved networks that prioritize attention allocation.

Furthermore, notifications activate brain regions that associate information from multiple sensory modalities, or which are supramodal. Event-related action potentials and resulting attention have been shown to be enhanced when sensory stimuli from multiple modalities are linked by location and or timing.

Finally, notifications are delivered in ways that pair potential importance with uncertainty, much like a slot machine, to keep users' attention returning to social media platforms. A facebook notification might represent a salient social interaction from your latest post, but you need to engage with the platform in order to access this reward. Despite being repetitive, which is usually associated with the attenuation of attention by bottom-up processing, notifications and the systematic manner in which they are delivered, represent supramodal personally salient stimuli, critical for exploiting human attention.

Social media's platform's content designs also contribute to the magical ability of social media to sustain attention. Whether it's messages, posts, pictures, or video reels, content on social media platforms is presented to the consumer in an interactive, diverse and simple way. Attention is a scarce resource that can be redirected when it has processed the stimuli presented from the environment [1,3,5]. To take advantage of this aspect of human attention, social media content is audiovisual and is presented in short, easy-to-digest ways, with a high emphasis on novelty. This results in exposure to content that will renew our attention cycle by repeatedly recapturing our attention. Social media's trick is beyond simple. Content is not shown in a chronological nature but rather uses big data, artificial intelligence, and supercomputers to show us content most likely to re-engage our attention.

What themes have been shown to keep more people engaged? Misinformation, disinformation, hurtful content (thanks to our negativity bias), and novel and surprising content [1]. Tristan Harris calls this, “a race to the bottom of the brain stem” because social media will show you what will instinctively demand your attention. Adverse effects of this type of manipulated sustained engagement are apparent in the mental health of users, polarization of discourse, and the spread of disinformation on these platforms.

When social media is exploiting the limitations of human attention networks, it is using content that plays on our biological impulses to be a part of something bigger than ourselves, socialize, be rewarded, and engage with novel stimuli. Neuropsychology describes attention as being dependent on the stimuli’s magnitude, novelty, degree of orientation toward a goal, and personal relevance [1]. All of which are deliberately exploited by social media to sustain consumer attention and therefore engagement with their products. Clearly, the illusion of attentional choice is magical thinking when investigating the tricks that social media uses to exploit our attention.

THE NEUROSCIENCE OF DREAMS

ELLA GAMBELL

Dreams have been a mystery of the human experience since the beginning of recorded history. What are these worlds we visit while we sleep, and what do dreams mean? These experiences often have emotional valence that leaves us wondering how they represent our daily lives as we awaken. Thoughts of dreams can persist throughout the day. They can even be so emotionally salient that they are encoded in long-term memory and come back into awareness long after they are dreamt. Dreams have been interpreted religiously and spiritually while inspiring artists, writers, and musicians throughout centuries. They are a fundamental part of being human and play a vital role in the developing field of the neuroscience of consciousness.

Humans spend one-third of their lives sleeping, and according to EEG studies, there are five stages of sleep [12]. The first four are “slow-wave” or non-rapid eye movement (NREM) sleep. The fifth stage is rapid eye movement (REM) sleep. This is when brain activity, blood pressure, metabolism, and heart rate are most like the waking state. Although dreaming occurs during NREM sleep, most reported dreams are from REM sleep, the research focus.

Consciousness is the state we are in while awake and is defined as being mentally aware and active [2]. During dreaming, our state of mind is subconscious. This means that there is significant mental activity without perceiving one’s state of consciousness. Lastly, there is the unconscious, with little brain connectivity and activity compared to wakefulness.

Photo: *Dream Within A Dream* - Ella Gambell (2018)

WHY DO WE DREAM?

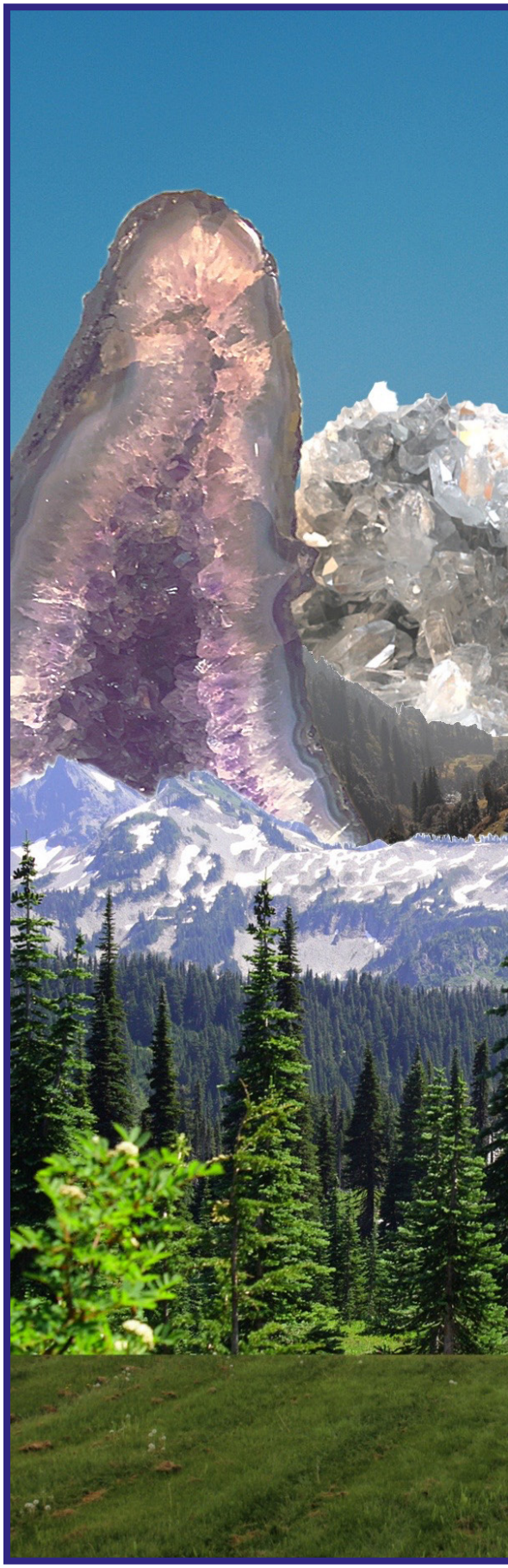
Dream research relies highly on empirical data. Despite there being a century worth of scientific evidence, there is no solid agreement on the purpose of dreams. However, there are three prominent scientific theories. The first is by the father of psychoanalysis, Sigmund Freud. He detailed his explanation for dreaming in ***The Interpretation of Dreams*** in 1910 [15]. Then, there is the Activation Synthesis Hypothesis by J Allan Hobson from 1977 [1] and G William Domhoff's Neurocognitive Model of Dreaming from 2001 [3].

- THE INTERPRETATION OF DREAMS -

Sigmund Freud believed that the answers to one's psychological ailments are hidden in the unconscious and that dreams are the gateway to these answers. So, his fundamental questions were, what are the contents of dreams, and how do they work together with the waking mind's experiences?

He determined that the contents are stimuli from the external world, the dreamer's subjective experiences, organic stimuli within the body, and mental activities during sleep [2]. Freud hypothesized that dreams serve the role of memory consolidation. He claimed that dream content is "day residues" that reflect the dreamer's activities from the day before the dream [15]. He also proposed the "dream lag effect," where the content in dreams could be from 5-to 7 days prior [15].

Freud also speculated that dreams contain important information about the dreamer. He believed that dream content comes from our real lives, but it is not identical [15]. Therefore, there must be a transformation and connection between the two. He claimed that these connections are not random – they are caused by a person's unconscious desires, which alludes to the saying, "a dream is a fulfillment of a wish" [1].



- ACTIVATION SYNTHESIS HYPOTHESIS -

Many decades later, J. Allan Hobson used more concrete neuroscience evidence to propose the Activation Synthesis Hypothesis[1]. With the knowledge that REM sleep is driven by brainstem reticular formation activation, he claimed that dream bizarreness is explained by random brainstem activation and deactivation of the dorsolateral prefrontal cortex (dlPFC)[1].

Hobson postulated that this chaotic bottom-up activation of the sensory cortex starts in the brainstem [1]. Then, additional activation of the visual cortex and secondary interpretation by higher-order frontal areas could produce dreams. Moreover, he believed that the narratives of dreams could be images from memory that are conjured up to instill meaning in random signals.

- NEUROCOGNITIVE MODEL OF DREAMING -

G. William Domhoff proposed a top-down theory with the Neurocognitive Model of Dreaming[3]. This theory is based on three independent areas of research. The first one is neuroimaging studies on participants with brain lesions. These revealed that some brain areas are not necessary for dreaming to occur. Additionally, dreaming depends on the normal function of a network located in the forebrain's limbic, paralimbic, and associational areas [3].

Another research area Domhoff investigated was developmental sleep studies in children ages 3-15 [3]. In children up to age 9, only 20-30% of REM awakenings led to dream reports. In addition, dreams in children under the age of five are static and mundane in content. Domhoff concluded that dreaming is a cognitive ability developed around 9 years old.

Lastly, Domhoff used data from a quantitative investigation into a content analysis of dreams. He found a repetitive nature of dream content that is continuous with waking life conceptions and emotional preoccupations [3]. Dream content contains a lot of previously unrecognized repetition in social interactions, characters, misfortunes, negative emotions, and themes. With this in mind, Domhoff claimed that dreams are the purest form of imagination [2].

DREAMS & PSYCHEDELICS

The psychedelic experience also shows a remarkable correlation to the dreaming state, and both can provide insight into the other. Both states of mind can be seen as a portal into creativity. Famously, during a dream, Mary Shelley got the inspiration for "Frankenstein," and Paul McCartney found the tune for the Beatles' song "Yesterday [6,7]." Similarly, the psychedelic state has given thinkers ammunition for great ideas, such as Apple founder Steve Jobs and the idea of personal computing, in addition to Alex Grey's *Sacred Mirrors* [5,13].

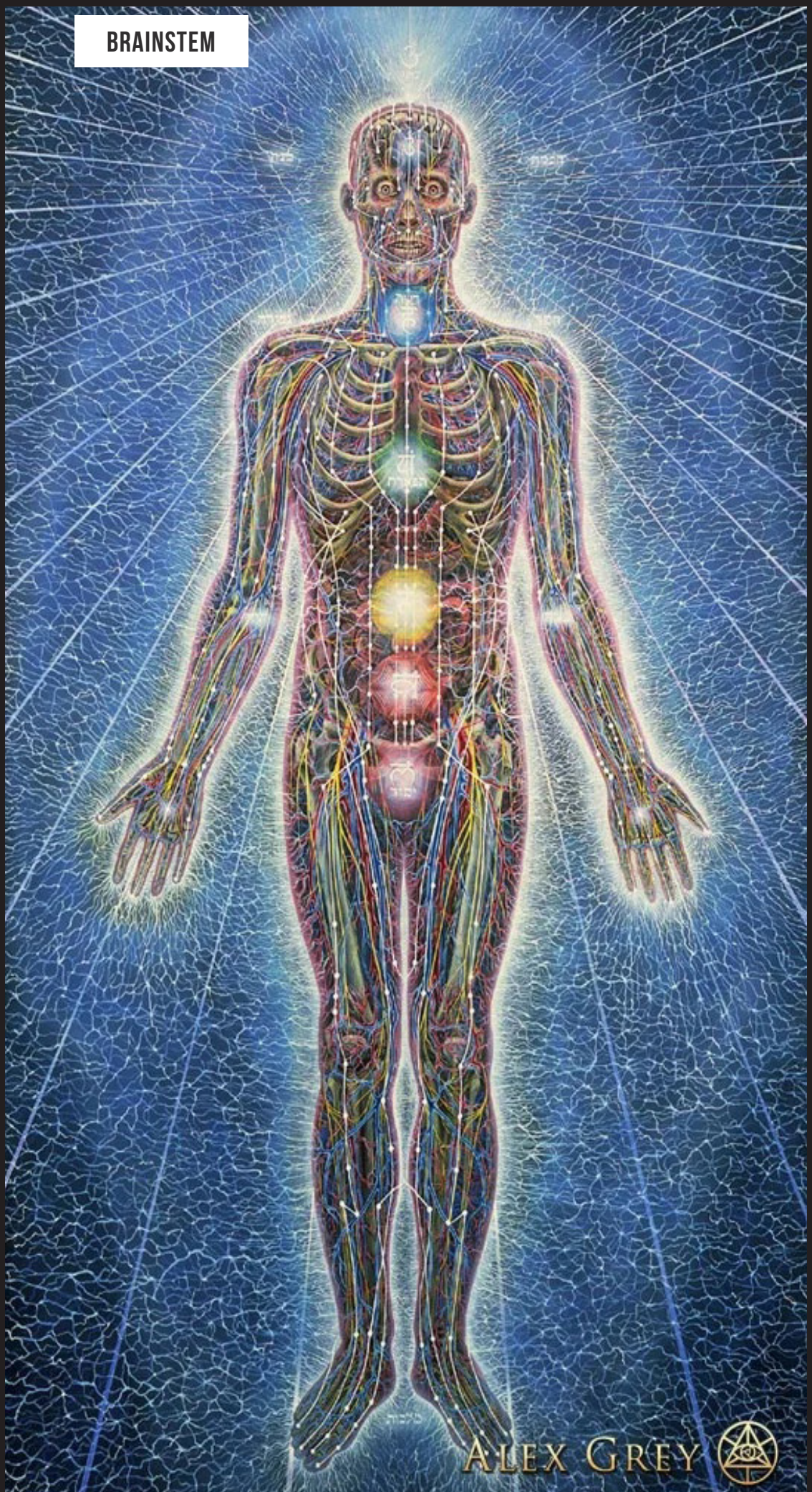
Dreams can be thought of as a prototypical hallucinatory experience, and psychedelic states can be seen as "experimental dreams" [8]. Interestingly, the neurotransmitter serotonin is crucially involved in our sleep/wake cycles. The serotonin 5-HT2A receptor is the primary target for psychedelics such as LSD, where activation is indicative of a hallucinogenic experience [11].

The psychedelic experience and dreaming both activate emotions and promote fear memory extinction [8]. One evolutionary theory about the purpose of dreams is that they provide a space to act out scary scenarios in a safe setting that can prepare the dreamer for harm while awake. For example, being chased by a predator simulates the scenario without the actual threat but can also act out potential ways of escape. With that being said... there could be a purpose to your nightmares!

Moreover, in dreams, the self is re-exposed to a conditioned fear stimulus (i.e., the predator). This gradual exposure to fear-conditioned stimuli without the actual reinforcement leads to a gradual decrease in the fear-conditioned response [8]. So perhaps, if you have recurring nightmares such as public speaking, your brain is training you not to be afraid when you get in front of a crowd during your waking life. Similarly, psychedelics enhance associative learning in memory consolidation [8]. In fact, there are promising results in clinical trials of psychedelics being used to treat PTSD.

The bizarreness of REM dreams can be attributed to a deactivation in the parietal cortex and the dorsolateral prefrontal cortex (dlPFC), a region associated with context-dependent decision making and time perception, mood regulation, and theory of mind [8]. The lack of activation in this region during dreaming decreases logic reasoning, which gives dreams the cognitive advantage of facilitating creative insight compared to the waking mind [8]. Similarly, reduced activity in the dlPFC after taking certain psychedelics is correlated with creative problem-solving.

Dreams and psychedelic experiences share the characteristic of losing self and body boundaries. However, they differ in the perspective of the self. Dreams are self-centered, where we are the protagonist of the story. The psychedelic experience shifts a self-centered perspective into selflessness, which connects the person to people and the environment in nondual awareness [8]. Both dreams and psychedelics could have therapeutic implications, where dreams can promote self-knowledge, and a psychedelic experience can promote transcendence of self-judgment.



THE CHAPEL OF SACRED MIRRORS

This image is one of several paintings in Alex Grey's Chapel of Sacred Mirrors[13]

Alex Grey is an exceptional visionary artist based in upstate New York.

The Sacred Mirrors are 21 life-size paintings of anatomically correct bodies that detail the physical and metaphysical anatomy of humans [13]. The paintings span from the skeleton, musculature, nervous system, and energetic fields of individuals.

Grey's goal for the Sacred Mirrors is for the viewer to stand in front of the paintings and "mirror" the different layers of human beings.[13].

LUCID DREAMING

What if you could control your dreams, where you could teach yourself how to fly or go anywhere that you want in the world? A subset of the population has this gift– the ability to lucid dream. However, anybody can train themselves to do this. For example, it is rumored that you can induce lucid dreaming by drinking apple juice or mugwort tea before sleep [10,14]. Although these methods are not proven, neuroscientific research has begun to decode lucid dreaming as a way to gain insight into consciousness.

Jose, age 23, from Santiago, Chlie, is an Economics and Energy double major at Western Washington University. Jose has been lucid dreaming for as long as he can remember. He explores magical worlds at his command while asleep, such as willing into existence a surreal garden or waterfall right before his eyes. Jose says that lucid dreaming feels like creating a story in which you move throughout space, exploring things with an omniscient narrator (Jose Ortuzar, personal communication, April 12th, 2022).

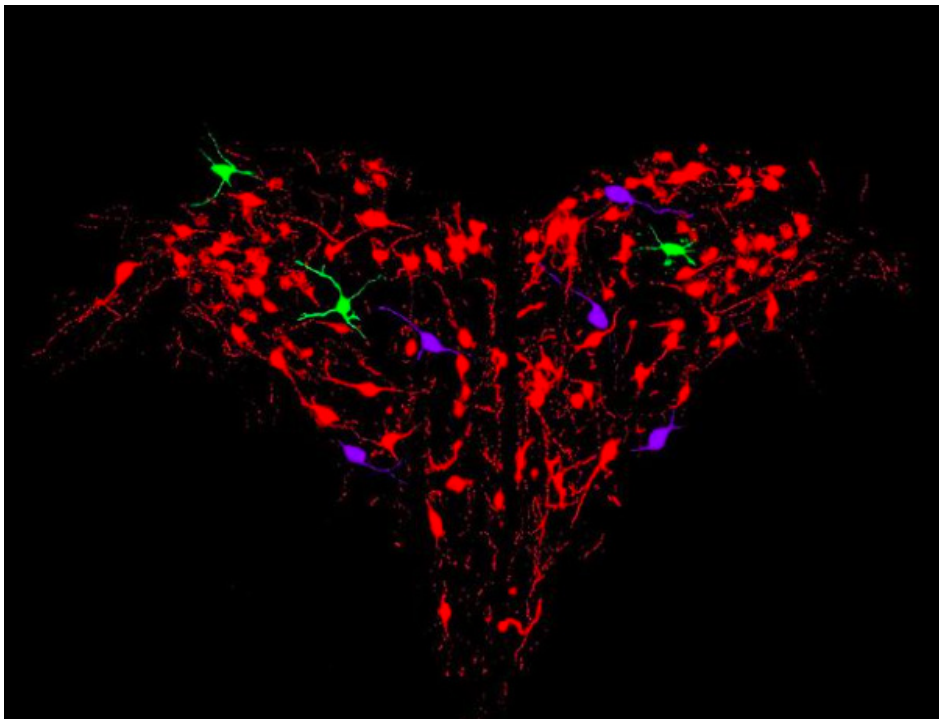
Cognitive neuroscience defines lucid dreaming as when a person is physiologically asleep but awake during dreaming. Research has proven this by instructing lucid dreamers to perform a sequence of eye movements while sleeping. Through electrooculogram (EOG) recordings, researchers found that dreamers consciously moved their eyes while dreaming [4].

As opposed to average dreaming and mind wandering, lucid dreaming involves metacognition, which is our awareness of ourselves as the thinker [4]. During REM sleep, there is deactivation in the dlPFC, which is hypothesized to be responsible for decreases in metacognitive monitoring, impaired critical thinking, restricted volition, and lack of insight into one's state of mind [4]. Conversely, for lucid dreamers, there is an activation in these prefrontal areas, giving them control over the dream narrative.

Lucid dreaming has clinical implications, with promise in treating nightmares and narcolepsy. By training people with nightmares to be lucid during their dreams, these people can realize that there is no actual threat and to not be afraid. Evidence has proven that lucid dreaming can reduce nightmare frequency. For narcolepsy, research has demonstrated that lucid dreaming can give patients psychological relief from narcoleptic episodes [4].

The fantastical ability to lucid dream gives humans the potential to fulfill their wildest imaginations.

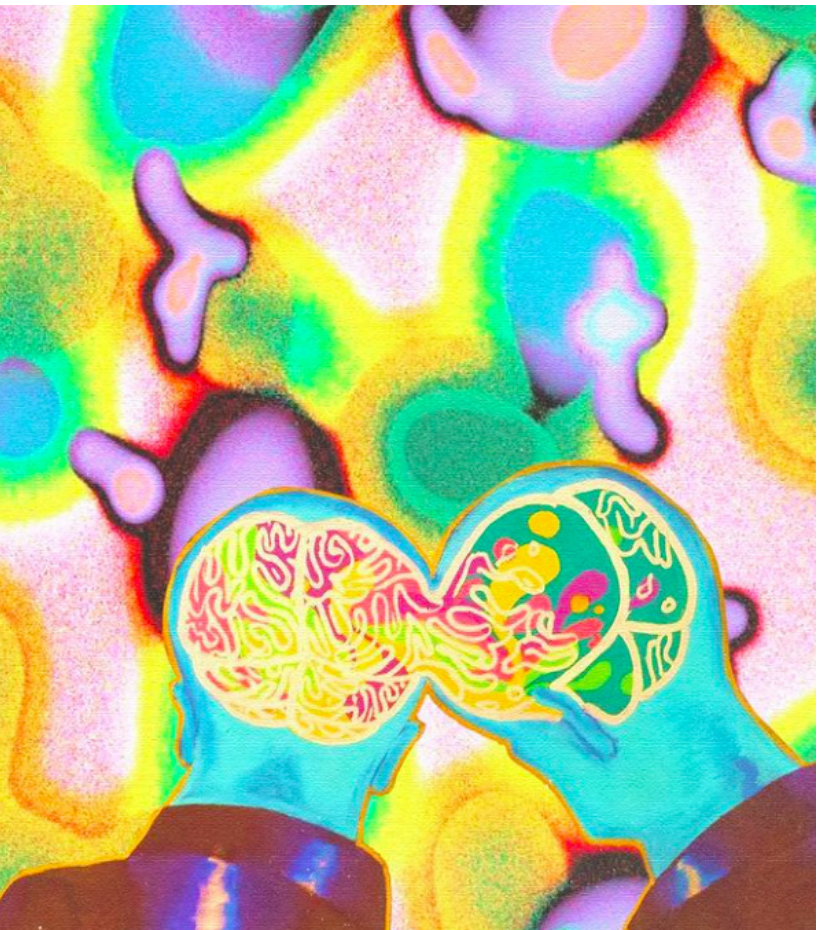
Whether dreams fulfill our unconscious desires, are our brains trying to make sense of spontaneous neuronal activity, or are the purest form of imagination, they continue to be a natural wonder that leaves people waking up in the morning questioning their reality. Dreams and the psychedelic experience share many similarities, such as activation of memories and fear memory extinction. Some people have the ability to control the narratives of their dreams, allowing their most fantastic imaginations to come to life. Science has made many advancements in dream research over the last century, but there is still vast untapped knowledge to discover.



Using electrophysiological recording and biocytin immunostaining, a heart-shaped population of oxytocin neurons (red) can be shown as they reside in the caudal paraventricular nucleus of the hypothalamus. Magnocellular neurons are shown in purple and parvocellular neurons are shown in green. Image by Lei Xiao.

Addicted to Love:

BECCA MARX



What is love? This is the age-old question that has been asked for millennia. The topic of love has dominated the arts for thousands of years, with historical records dating back to the first of written history in the Mesopotamian era[1]. What starts as an attraction begins to transform to a likening, until that feeling transforms more and grows to love. Love touches a wide spectrum of emotions: from euphoric and playful, to peaceful and tender. But what makes us feel these complex emotions?

Hell of a Drug

LOVE IS A DRUG

It is commonly known that the dopaminergic reward system is activated by many recreational drugs. However, it is less known that the same reinforcement reward system is also activated while in love[2]. In other words, the phrase, “love is a drug” is fairly accurate. Now, this begs the question of why our bodies are designed to seek out love. Do ooey-gooey feelings exist for a purpose? Why would the pleasurable feelings associated with being in love be advantageous for our survival? Research suggests that these feelings strengthen the need for mate selection as it is evolutionarily beneficial to have a strong bond with a partner for the most successful parenting[2]. While certainly not all in love are looking to parent, this provides a logical explanation for why love exists from an evolutionary perspective: to continue on the cycle of life and reproduce. However, this does not explain love outside of the heteronormative and binary, nor does it offer an explanation for non-sexual love.

LOVE IS BLIND

It is also said that love is blind. As it turns out, this saying is also based in truth. The cerebral cortex and basal forebrain are brain areas that regulate social interactions and increase social vigilance and caution. Under the influence of love, both areas have decreased activity[2]. This offers an explanation as to why we can let down our guard so easily in love and have a hard time identifying “red flags” in romantic relationships without practice. Our brains are built to be less cautious and see lovers through rose-colored glasses while we are basking in the glory of our new partner. This is evolutionarily beneficial because it is favorable to have a strong bond with a co-parent for child rearing[2]. Thus, we give our partners the benefit of the doubt. We let down our guards and relinquish our shields. However, for some, love can cause the opposite to occur. This is often due to differences in upbringing and environmental experiences that shape our attachment style and feelings towards partnership.

There are three established attachment styles: anxious, avoidant, and secure[3]. An individual with an anxious attachment style has a strong desire for closeness that nears co-dependency while also fearing abandonment. In contrast, avoidant attachment is characterized by a fear of dependence on others and a struggle with emotional intimacy. Lastly, secure love meets these polarities of dependence and intimacy in the middle: emotions and trust flow freely, and self-confidence reigns high. A secure individual seeks out social support when needed and isn't afraid of vulnerability. You now may be asking the obvious: what can be done to mend my conditioned attachment style if I don't typically feel secure in love? Perhaps unsurprisingly, the answer is therapy. Psychotherapy has shown to be an effective tool for reshaping the way we view ourselves and our relationships[4]. The power of the mind is extraordinary, and we have the choice to reframe our thoughts through practice which in turn rewires neural connections. No one is saying it's easy, but we could all probably use some therapeutic reflection and hard work with a therapist in order to work on our connections towards love and take inventory of what has caused our previous breakdowns to occur.

LOVE HEALS ALL

It has been shown that oxytocin, also known as the love hormone, can facilitate neurogenesis in adults after a stressful experience[5]. Oxytocin is perhaps more well-known for its facilitative role in birth, lactation, and overall caretaking behavior in the parent-child relationship. Early exposure during critical developmental years has been found to regulate our ability to both form social bonds and to love. Additionally, rats with physical injuries in social isolation heal slower than rats surrounded by community. This increase in wound healing is thought to be associated with the presence of more oxytocin in the social animal than in the isolated animal[6].

MONOGAMOUS LOVE

What do prairie voles have to do with love? Surprisingly, the vole makes for a great research subject for studying monogamy and love hormones, as the rodents mate for life with a single partner. The love hormones of greatest interest are oxytocin and vasopressin. Vasopressin is associated with protective aggression and guarding behaviors of a partner[7]. Research shows that the monogamous prairie voles have more oxytocin and vasopressin receptors in the nucleus accumbens, caudate-putamen, and ventral pallidum compared to similar species of vole that do not mate for life and are sexually promiscuous[8]. These are also the brain areas that play a role in reward, reinforcement, and addictive behaviors. The above brain areas are also abundant with dopaminergic neurons- the neurotransmitter responsible for rewarding and reinforcing feelings of pleasure. The role of oxytocin, vasopressin, and dopamine in the reward pathway in relation to love continues to reveal itself. When prairie voles are given vasopressin and dopamine antagonists (or in other words, when the binding of vasopressin and dopamine are blocked) the voles become promiscuous and lose interest in their lifelong partner and pair bonding is eliminated[8]. If dopamine and vasopressin fuel our monogamous relationships, the question still remains... How do we get into partnership in the first place?

LUST

Sensitivity to androgen and estrogen odorants reliably coorelate with sexual attraction, regardness of sex designated at birth. While discussing sexual orientation and attraction, it is imperative to remember that gender is purely a social construct and that bodies do exist outside of the binary of just strictly male or female. Keeping these facts in mind, it has been found that people attracted to men, such as straight women and gay men, are more responsive to androgens, or male sex hormones in the anterior hypothalamus[9]. For people attracted to women, estrogens maximally activate their anterior hypothalamus. This data exemplifies the neurobiological differences in attraction- it is not just a feeling, but rather a state of neurological being. When discussing sexual attraction, the topic of lust versus love cannot be forgotten.

Passionate love is neurologically different from lust [10]. Data shows that the posterior insula is more activated during feelings of lust, and the anterior insula is more activated during feelings of love[11]. This neural difference is also reinforced by a case study in which a patient had a brain lesion in the anterior insula and struggled with feelings of love, but not lust[12]. This means that lust and love not only subjectively feel different, but that they are separate experiences that do not necessarily have to coexist. While we have a lot to learn about love, perhaps love has even more to teach us. Undoubtedly, love is like a drug in the best sense- it can be highly therapeutic and a pathway for deeper self-knowledge for those brave enough to feel it. The best thing we can do is love ourselves where we're at and offer our partner the same gift.

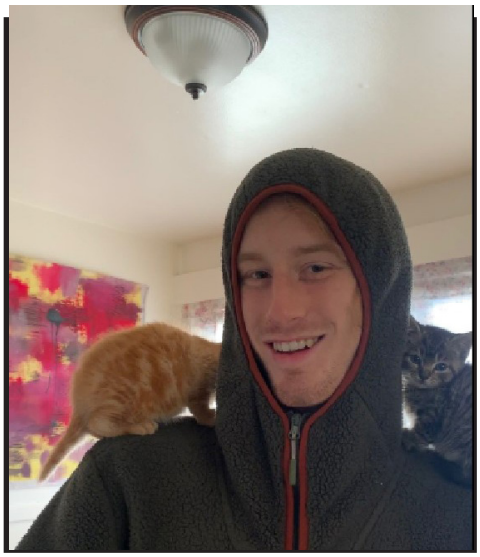
UNDOUBTEDLY, LOVE IS LIKE A DRUG IN THE BEST SENSE- IT CAN BE HIGHLY THERAPEUTIC AND A PATHWAY FOR DEEPER SELF-KNOWLEDGE FOR THOSE BRAVE ENOUGH TO FEEL IT. THE BEST THING WE CAN DO IS LOVE OURSELVES WHERE WE'RE AT AND OFFER OUR PARTNER THE SAME GIFT.

ABOUT THE AUTHORS

Ella Gambell
Philadelphia, PA

Ella grew up on the east coast and chose to venture out west for her undergraduate degree because of her love for travel and nature. After high school, Ella took a gap year to travel throughout India and to work on a permaculture farm in Australia. Ella spent most of her adolescence preparing to go to art school, but her curiosity for the science of consciousness led her to pursue a degree in Behavioral Neuroscience.

Ella is a certified yoga instructor and spent her sophomore year teaching classes at WWU's recreation center. She went on to become a research technician for Dr. Josh Kaplan's neuropharmacology and neurophysiology lab, where she investigated the therapeutic potential of cannabidiol (CBD) + cannabis terpenes, and the developmental effects of CBD. Ella has a passion for visual and written science communication and plans on building a career that blends her love for science and art. After graduating in Spring 2022, Ella intends to build an art portfolio for her applications to Medical and Biological Illustration master's programs.

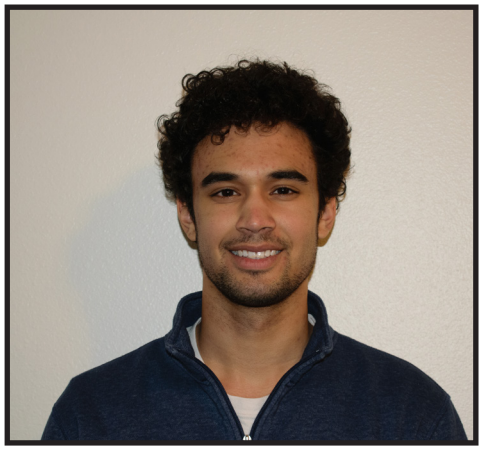


Jack Jones
Spokane, WA

Jack is graduating in June 2022 with a major in Behavioral Neuroscience (BNS), minors in chemistry, honors, and psychology and is pre-med. Drawn to neuroscience by his interest in psychedelics and their potential for furthering the areas of neuroscience and psychiatry, Jack enjoys learning about drug science and policy. Jack pursued these interests by working in Dr. Kaplan's cannabis lab studying the therapeutic potential of cannabigerol (CBG). He has served for two years as co-president of Western's Students for Sensible Drug Policy (SSDP) Chapter, a club that he helped co-found with co-writer Finn McGuinness.

During his junior year, Jack studied abroad at the University of Otago in New Zealand. Jack was a psychiatry intern and neurodiagnostic intern through the BNS internship opportunities. Jack enjoys volunteering through club outreach and at the Whatcom health center Safe Syringe Program. Post-Graduation, Jack has plans to travel in Europe and South America with his twin brother. He plans to move to Seattle and continue working towards his career goal in psychiatry by working in fields relating to mental health, drug science, and neuroscience.

A special thanks to Dr. Grimm and Andrea Swanson for helping us create this magazine.



Michael Kihanya
Bellevue, WA

Michael is a neuroscientist and auditory explorer. His studies at Western Washington University intersect Behavioral Neuroscience and Audio Technology. In graduate school and beyond, Michael's objective is to combine artistic and empirical work to explore our brain's interactions with sound, while implementing discoveries into clinical and therapeutic settings. He hopes to use neuroscience in engaging with the currently-unknown qualities of sound to promote healing in human brains. Michael believes the questions we have about the brain can be intentionally approached through both art and science.

As a musician and creative, Michael plays saxophone, piano, and drums. He has extensive experience in DAWs (Digital Audio Workstations) such as FL Studio, Logic Pro, and Pro Tools. Moreover, his studies in audio technology have prepared Michael to step into any professional studio with confidence. His musical influences include Scott Mescudi, Kay Gardner, Laraaji, Bob Dylan, Thebe Kgositsile, The Ramones, and Rick Rubin. As an undergraduate, Michael's research experience includes recording ultrasonic vocalizations (USVs) in C57BL/6J and BTBR T+tf/J mice to assess sociability. He developed protocols linking bioacoustics and convolution neural network processing. When Michael is not studying for his next midterm, he enjoys running, reading, writing poetry, and playing lacrosse.

Becca will be graduating Spring 2022 with a degree in Behavioral Neuroscience and a minor in Psychology. She has had the pleasure to work as an undergraduate research assistant under Dr. Jeff Grimm investigating the neurobiology of relapse and has endless appreciation for his mentorship over the past 3 years. She currently serves as President of the Neuroscience Research Driven Students (NeRDS) club on campus and has continued the legacy of the club through a dedication to accessibility of neuroscience topics for all students. Following her passions of evidence-based drug education and harm reduction advocacy, she also serves as Community Outreach Coordinator for Students for Sensible Drug Policy (SSDP).

Becca has begun working as a transcranial magnetic stimulation (TMS) and Esketamine Technician at SeattleNTC in their Bellingham location. This opportunity cannot go without thanks to Dr. Hank Levine, whom she worked with this past winter under the BNS Undergraduate Internship Program in Psychiatry. Her future endeavors include obtaining a doctoral degree to follow her passion in psychedelic medicine and science, but in the meantime she can be found mountain biking, skiing, and otherwise chasing endorphins.

Becca Marx
Juneau, AK

Finn McGuinness
Spokane, WA

Finn is a soon-to-be BNS graduate, whose interests lay at the intersection of neuroscience, computer science, physics, and anything to do with psychoactive drugs. He is a long-time member of the Kaplan research lab on campus, where he uses behavioral and electrophysiological techniques to study the therapeutic value and developmental effects of chemicals found in the cannabis plant. He is also a member of Dr. Jennifer McCabe's clinical psychology lab, which focuses on maternal and perinatal health.

Outside of research, Finn is a founding member and co-president of WWU's Students for Sensible Drug Policy club, along with Jack Jones. Additionally, Finn is a leader of the Molecular Bioscience club on campus. Finn's long-term goals are to be a leading researcher in his field, to communicate science to lay communities and increase scientific literacy, and to advocate for more compassionate, science-based drug policies, in order to make drug research more accessible.

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Addicted to Love: Hell of a Drug

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The authors enjoying a leisurely game of hacky sack on a warm Spring day on campus.