GREY MATTERS CU

Spring 2024

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by Qingyang Meng

ABOUT US

The *Grey Matters Journal* at Columbia University is an undergraduate neuroscience journal dedicated to the exploration of the brain's many mysteries. We provide a space for undergraduates interested in neuroscience, no matter their program, to research and write about their favorite topics in this ever-expanding field. Our mission of exploration does not stop, however, at giving budding scientists a place for their work. We believe that everyone should be able to read our articles, no matter how complex the topic may be. With three skilled editorial divisions, we ensure that each article is written for even the most casual readers, and that our articles lose no depth in the process. In doing so, we invite readers new to neuroscience to explore the brain through the delicately crafted art and writing between these covers.

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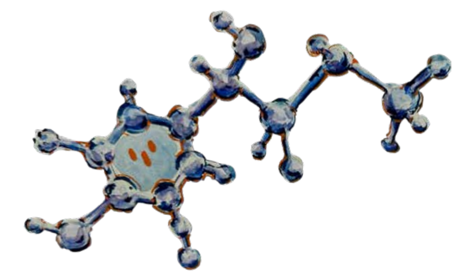


Work Hard, Play Harder
by HeeJee Yoon

In the midst of a bustling playground, a child's laughter fills the air as they dart and dash, tagging friends with lightning speed. What seems like childish nonsense is actually a fascinating game for our brains, dynamically evolving with each playful interaction. Let's tap into the wisdom from our childhood selves and explore the timeless wonder of play, discovering the boundless potential it holds for our minds– no matter our age.

Whispers of the Deep
by Laura Mittelman

Have you ever wondered what it would be like to *see* the world through sound? For sperm whales, this intriguing capability is a reality. Equipped with one of the most robust acoustic signaling devices in the animal kingdom, sperm whales can navigate the dark ocean and communicate with their pod solely through echolocation. Dive deep beneath the waves to uncover the astonishing intelligence and sophisticated vocalizations of these majestic mammals.

Seeing Double
by Sabrina Hsu

Your best friend has vanished overnight. Even worse, an identical-looking…*thing*…has taken their place. An expert mimic, whose every grin, whisper, glance is an exact, bone-chilling replica. As you stare into the eyes of this impostor wearing your friend like a taxidermy shell, you wonder: Will I be next? Is this a nightmare?

EDITOR'S NOTE

Dear Reader,

I am so excited that you have picked up, clicked on, or stumbled across this issue of *Grey Matters*. The publication of this issue, our seventh, signifies a major stepping-stone in the trajectory of *Grey Matters CU*. The staff graduating this year, in May 2024, consists of the last students who were at Columbia when *Grey Matters* took its baby steps in Spring 2021. I can't help but experience an overwhelming sense of awe when I look around at the passionate community of neuroscience lovers that was born and realize that we have now published seven issues.

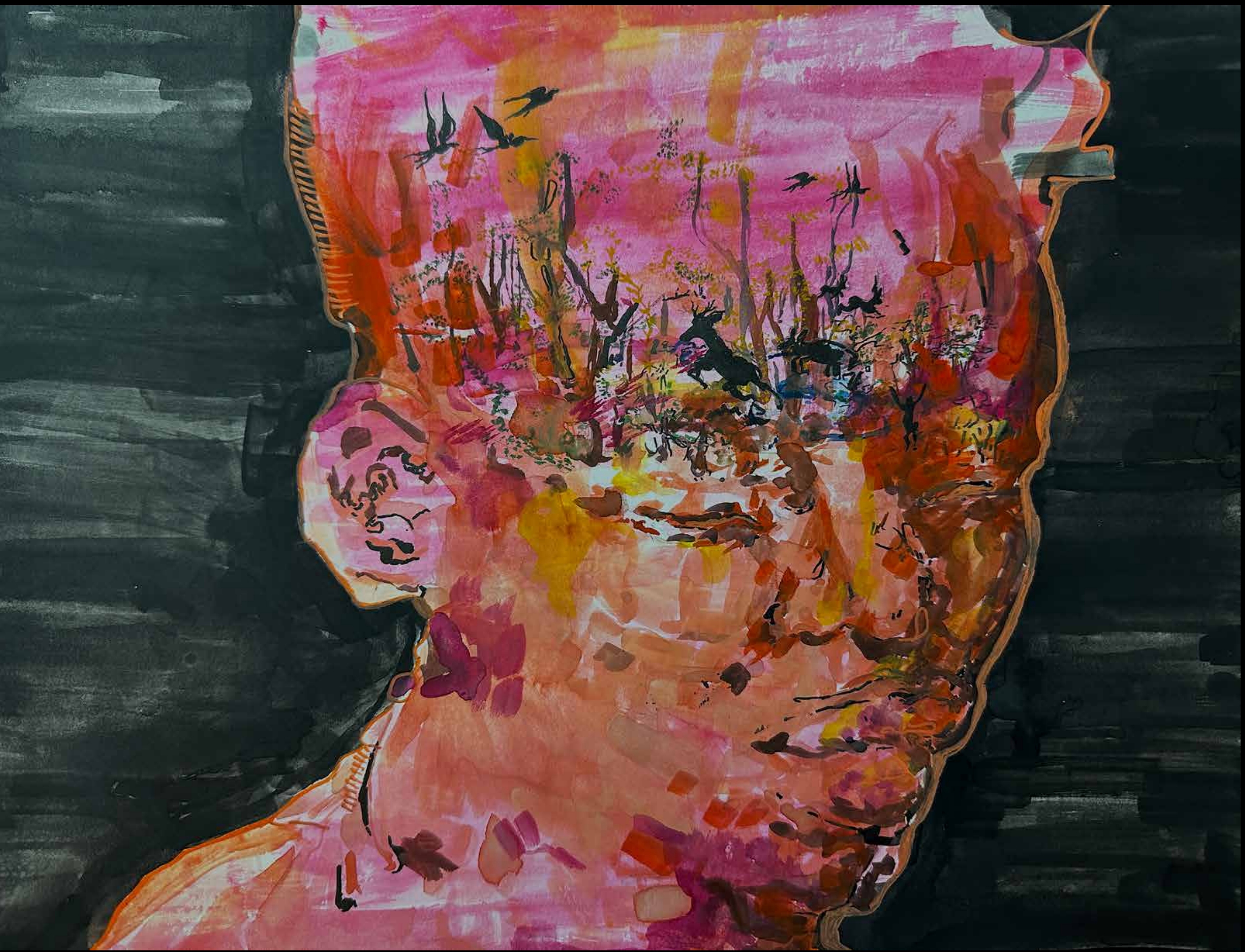
When I speak with the team here, there is a pervasive feeling of pride in our growth. Every member of the *Grey Matters* community over the past four years has not only contributed to the material on these pages but has dedicated their time to investing in the production of accessible and interdisciplinary science communication. While there will inevitably be growing pains, I urge future members to often return to this common goal. In the spirit of continual growth, we have designed this issue to mirror human development.

This issue illustrates the process of growing up by beginning with an article about nurturing your inner child through play and ending with an article about age-old folklore potentially rooted in neuropathology. Between these bookends are articles on the science of storytelling and the reason we have a visceral connection to the smell of mom's banana bread. We also touch on the not-so-whimsical parts of growing up — the pressure of perfection and the potential for overstimulation in our digital world. In the middle of the issue, we hope to remind readers of the sheer beauty of the neurological systems that allow organisms to communicate. By understanding the innate ability to connect, we can strive to use our own unique capabilities as humans to create and identify with our communities.

As scientists, writers, editors, and thinkers who are passionate about academic accessibility, we have an obligation to foster an environment that values diverse perspectives. In fact, science would be grossly incomplete without the contributions of people from all over the world who think differently from each other. As we print issue after issue about the neuroscience of humanity, it is of the utmost importance that we acknowledge that being able to produce and publish these articles is a privilege in itself. We publish this issue against the backdrop of a humanitarian crisis resulting in the mobilization of many of our staff and peers as they advocate for academic freedom and the rights of people across the globe. At a time when empathy is needed the most, I sincerely hope that reading this issue will remind you of some common threads that we all share: listening to grandma's stories, playing tag, and remembering past lovers by a whiff of their perfume. With mutual understanding, we will be able to continue to grow together. Working with GMCU has been the pleasure of my lifetime. Thank you.

Love,

Isabella Cannava
Editor-in-Chief



Work Hard, Play Harder

by HeeJee Yoon
art by Sydney Eze

We Used to Play

"What do you do for fun?"

Bogged down by a literature essay and a looming chemistry exam, I felt a fundamental lack of playful energy in my life. Looking for inspiration, I asked my friend and fellow Grey Matters member, Ben, what he did for fun. Despite being a simple question, it elicited a complicated response consisting of a shrug and a look of disbelief at our inability to answer such a simple question. We shared bittersweet laughter, joking that this is the epitome of the "Columbia experience": constantly living under the slogan of 'work hard, play hard,' but somehow always leaving out the second half of the motto.

I decided a better person to ask about fun would be my 10-year-old self. So, I asked her, "How do you have fun?" Graciously stopping in the middle of a game of tag, she pants, "Play, of course."

This straightforward response prompted me to consider: what exactly is play? According to Dr. Stuart Brown, a psychiatrist at the National Institute for Play, play is an activity pursued for its own sake—not for profit or recognition [1]. It's voluntary, energizing, and takes us beyond ourselves [1].

Reflecting on the importance of play in my own childhood and in the lives of others, I wonder: what role does play serve, and should I prioritize fostering this spirit of playfulness amidst the demands of college life?

We Play to Survive

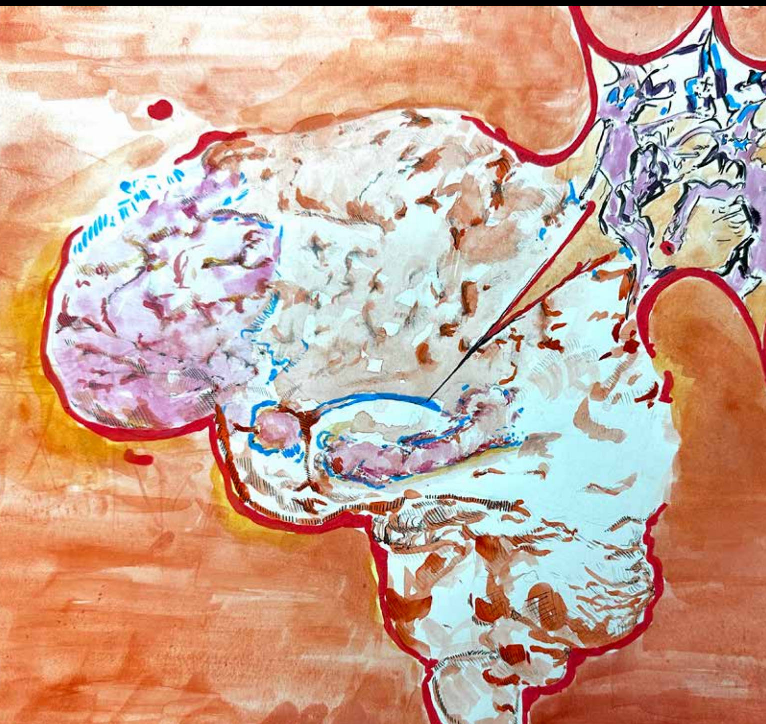
From the intense wrestling matches of young wolves to the intricate social games of primates, play permeates the tapestry of mammalian life, hinting at deeper evolutionary significance where play is more than just child's play—it's a serious business. Initially, theories such as the surplus energy hypothesis proposed that play was nothing more than a way for young animals to expend their excess energy [2]. However, Karl Groos, a German philosopher and psychologist in the 20th century, proposed an evolutionary perspective, suggesting that play serves as a strategic investment in teaching the young how to survive [3]. The seemingly pointless roughhousing actually provides a training ground for animals to develop skills crucial for navigating the survival challenges of an environment, from mastering evasion tactics to honing social interactions and dominance displays [3].

Though humans aren't constantly preparing to flee from predators, our brains still carry our ancestors' survival instincts in the form of the triune brain [4]. Paul MacLean's idea of the "triune brain" highlights three key brain regions: the brain stem, the limbic system, and the cortex [5]. MacLean hypothesized that these regions were amongst the most important in coping with environmental stress, placing extra emphasis on the limbic structures [6]. These structures, deeply intertwined with emotional response and instinctive survival mechanisms, serve as vital hubs for memory and emotion regulation, exemplified by the hippocampus and amygdala [6]. Even across evolutionary history, these limbic structures have remained remarkably unchanged, suggesting their fundamental importance [5].

> "*Through interactive and engaging activities inherent to play therapy sessions, individuals may experience heightened oxytocinergic activity, fostering feelings of trust, safety, and relaxation [32].*"

Indeed, research suggests that damage to the limbic structures in hamsters results in a noticeable decline in their play activity [7]. In contrast, altering the neocortex, an evolutionarily newer brain region found on the surface of the brain, does not significantly affect their play behavior [7]. Such results confirm the significance of evolutionary-conserved brain regions tasked with shaping human play behavior.

This is not to say that recently evolved brain regions have no impact on play. In fact, emerging research shows that even recently evolved brain regions, such as the prefrontal cortex, an area responsible for making judgment calls and regulating emotions, play a significant role in shaping both play behavior and survival instincts. A study conducted by Dr. Sergio Pellis involved denying rats the opportunity to engage in rough-and-tumble play, a category of play characterized by physical fighting and wrestling [8, 9]. As a consequence, deficiencies emerged



in their brain's prefrontal cortex. Pellis observed that rats deprived of play exhibited impaired decision-making abilities in survival scenarios. For instance, when an adult male was introduced into a foreign cage, the resident rat perceived them as an intruder and initiated a fight. A typically-developed rat would cleverly find a place to hide from the resident and remain there. However, a play-deprived rat, lacking the well-developed prefrontal cortex necessary for sound judgments, would endure a beating from the resident and then inexplicably return to the area to engage in further conflict, thereby drawing more attention to itself [8, 9]. Pellis's research underscores the vital role of rough-and-tumble play in rats for developing crucial survival skills and decision-making abilities, emphasizing its significance in shaping adaptive behavior. We will continue to explore these regions in the limbic systems and neocortical regions as they apply to different play scenarios.

We Play to Exercise Our Brain

The classic game of tag is more than just an exhilarating opportunity to demonstrate your prowess against a playground enemy; it's an opportunity to practice and enhance your executive functioning. Executive functioning refers to the ability to perform complex cognitive tasks like attending to specific stimuli, problem-solving, and practicing mental flexibility [10]. Mastery of executive functions is important for the success of children in both academic and social settings as they grow up, and has proven itself as a reliable predictor for competence as rated by teachers and parents in later education [11].

Executive functions employ brain regions like the hippocampus, a region recognized as the primary structure for memory [12]. In the lively game of tag, children unwittingly give their hippocampus a thorough workout. Of course, the act of remembering who's "it" and who's not flexes this cognitive muscle. Surprisingly, it's the act of fleeing during the game that truly builds this memory center.

To understand this concept, first, we turn our attention to the structure of the memory center. Like all brain regions, the hippocampus is made of brain cells called neurons that arrange themselves into networks in order to communicate with each other. The best hippocampal networks are the ones that are constantly changing and growing based on new experiences and environments. Returning to the idea of tag, a key component of the game is constant aerobic exercise. The long strides needed to escape from the tagger increase the amount of brain-derived neurotrophic factor (BDNF), an important molecule involved in allowing the hippocampus to operate optimally as a center for learning and memory [13]. BDNF makes our brain extra flexible in a way that benefits us. This molecule allows for synaptic plasticity, meaning it can change how strong our neural connections are, which is important for proper brain network development [14]. Additionally, an increase in BDNF is associated with a process known as neurogenesis, or the production of new brain cells [15]. Neurogenesis allows for the formation of new neural connections and the pruning of unnecessary ones, essential mechanisms for learning, memory formation, and cognitive development during these critical periods of life.

Let's refocus our attention on the synapse, the gaps between the neurons. Neurons communicate with each other through chemical messengers called neurotransmitters. In the process of fleeing from the tagger, our brain cells are ramping up the production of neurotransmitters associated with excitement, pleasure, and motivation – otherwise known as dopamine and adrenaline [16]. This surge in neurotransmitter activity is particularly pronounced in the limbic system [17]. In navigating our surroundings, whether it be strategizing our next move or assessing potential escape routes, our actions are influenced by perceptual and value-based decision-making processes. Perceptual decision-making involves interpreting sensory information to make judgments about our environment, while value-based

decision-making entails weighing the potential outcomes against our internal values and goals. Even amidst heightened activity in our limbic system, which is flooded with dopamine and adrenaline in response to various stimuli, we are continually refining our ability to operate effectively. This means that despite the emotional arousal that often accompanies our responses to stimuli during engaged activities, we enhance our capacity for reasoned decision-making and action execution [17].

We Play to Create and Connect

In the whimsical world of childhood imagination, where Barbie dolls reign supreme, children embark on fantastical journeys limited only by the bounds of their creativity. Picture this scene: a child, armed with their trusty Barbie doll, orchestrates a grand adventure, casting the doll as the intrepid leader of an underground mermaid city. Amidst the glittering waves and hidden caverns, Barbie navigates treacherous waters and foils dastardly plots—all in a day's play.

At the heart of this cognitive marvel lies the prefrontal cortex, a brain region teeming with promise, waiting for enriching ac-

tivities like pretend play to reach its maximum potential. In the field of neuroscience, creativity is highly related to the concept of divergent thinking, the cognitive ability to come up with ideas that lead in various directions [18].

Divergent thinking is most commonly used during pretend play when children suggest alternate uses for objects or create novel scenarios to roleplay. Neuroimaging studies have shown that areas in the prefrontal cortex are activated when participants are engaged in divergent thinking [19, 20]. Recall the role of the prefrontal cortex, a region associated with planning, prioritizing, and overall maturity. This is one of the last regions in our brain to fully develop because of its high cognitive functions [21]. Exercising this region early on in development through the low-stress situation of pretend play sets children up for healthy and productive cognitive development [22].

But what drives this creative endeavor? The hippocampus re-enters the discussion. As children weave Barbie through their fantastical narratives, they draw upon a rich tapestry of memories, infusing their play with depth and continuity. Neuroscientists have observed the hippocampus lighting up with neural activity as children recall past adventures, highlighting its crucial role in shaping the narrative landscape of pretend play [23].

As children chart new territories with Barbie by their side, they engage in a form of mental time travel—a phenomenon rooted in the intricate interplay of episodic memory and future planning. Studies with rodents navigating mazes have unveiled the neural underpinnings of this cognitive marvel, with the hippocampus playing a pivotal role in constructing cognitive maps and anticipating future navigational paths [24, 25].

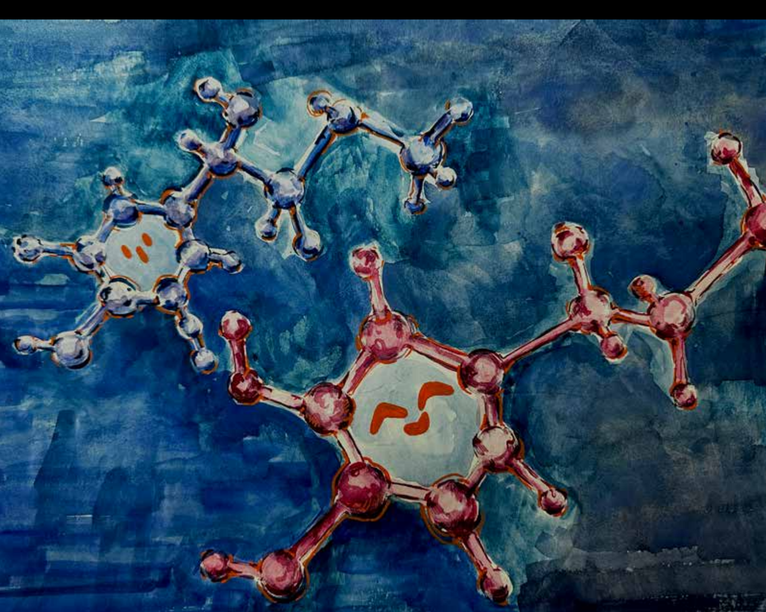
But what about the metacognitive dexterity at play? Pretend play offers a fertile ground for the cultivation of metacognitive skills—the ability to think about one's own thinking [22]. As children navigate the twists and turns of their Barbie-inspired adventures, they engage in reflective imagination, pondering the motivations and intentions of their doll counterparts. This metacognitive mastery is underpinned by the gradual maturation of the brain's reflective circuits, paving the way for heightened self-awareness and social understanding [26].

A research study investigated this aspect of pretend play in-depth, observing its effect on developing social skills, particularly empathy, in children [22]. It has been widely established that the posterior superior temporal sulcus (PSTS) is a brain region associated with developing social understanding and empathy. Researchers used a functional neuroimaging technique called functional near-infrared spectroscopy to measure the activity in this region during pretend play. They discovered that in comparison to solo play on tablets, pretend play was associated with greater activation in the PSTS. Interestingly, this brain region was not only active when kids were playing pretend with other kids, but also when they played on their own [22].

We Play to Heal

Play therapy, particularly when applied to trauma treatment, engages intricate neurobiological processes, including the hypothalamic-pituitary-adrenal (HPA) axis [27]. The HPA axis serves as a central regulator of the mammalian stress response, orchestrating a cascade of hormone and neurotransmitter signals in response to stressors [27]. In response to a perceived threat, neurons in the hypothalamic paraventricular nucleus (PVN) release corticotropin-releasing hormone (CRH) [28]. This hormone traverses to the anterior pituitary gland, stimulating the secretion of adrenocorticotropic hormone (ACTH) [28]. ACTH then acts upon the adrenal glands, prompting the release of glucocorticoids, steroid hormones primarily involved in regulating metabolism and immune response, such as cortisol, into the bloodstream [29]. Glucocorticoids play multifaceted roles in modulating metabolism, immune function, and neural activity, thereby coordinating physiological and behavioral responses to stress [29]. In the context of trauma, dysregulation of the HPA axis is frequently observed, leading to abnormal cortisol levels and heightened stress responses [29].

Interestingly, play therapy appears to exert regulatory effects on the HPA axis, potentially mitigating the adverse effects of trauma-induced dysregulation [30]. By providing a safe and supportive environment for expression and exploration, play therapy may attenuate hyperactivity within the HPA axis, thereby promoting a return to homeostasis and facilitating stress recovery [30]. Furthermore, the physiological effects of play therapy encompass not only the interactions of the hypothalamic-pituitary-adrenal (HPA) axis, but also involve other brain pathways related to the release of oxytocin – a hormone involved in social bonding, trust, and stress modulation [31]. The release of oxytocin is associated with positive social interactions, including those facilitated by play therapy [31].



Through interactive and engaging activities inherent to play therapy sessions, individuals may experience heightened oxytocinergic activity, fostering feelings of trust, safety, and relaxation [32]. These neurochemical changes could counteract the negative effects of trauma, promoting emotional regulation and resilience [32].

Play therapy operates within a neurobiological framework encompassing the HPA axis and oxytocinergic system. By modulating stress-related neuroendocrine pathways, play therapy offers a promising avenue for trauma recovery, providing individuals with a safe and supportive environment conducive to healing and emotional regulation.

We Play to Have Fun

In a period of my life where time seems to be the most precious resource, I often find myself questioning the place of play in the realm of adulthood. Is it merely a relic of childhood to be discarded in the pursuit of success? Or, does it hold the key to unlocking a deeper, more fulfilling existence? Oftentimes, I can't help but feel the opportunity cost of having fun and playing: I could be getting ahead on next week's reading or contemplating acid-base problems. Delving into the neuroscience of play, I am reminded of the remarkable plasticity of the human brain. Contrary to popular belief, our brains are not static entities, but rather dynamic, ever-evolving structures capable of profound transformation throughout our lives. The concept of neuroplasticity teaches us that our brains have the remarkable ability to rewire and adapt in response to new experiences and environments, regardless of age. Through this article, I hope that one thing has become clear: the opportunity cost of NOT playing, where we risk losing out on moments for our brains to grow, heal, and laugh. As we climb the ladder of success, let's remember to pause and slide down the banister of playfulness every now and then. ♔

Scent-imental

by Sophia Virkar
art by Hailey Kopp

Introduction

Have you ever smelled a box of crayons and been transported to your second-grade classroom? Or maybe you caught a whiff of your mother's perfume and were reminded of how much you miss her? Our sense of smell, a crucial but often overlooked element of human perception, has the unique power to transport us back in time, connecting our emotions and memories. Beyond evoking nostalgia, scents also impact our social interactions and choices, from selecting romantic partners to influencing everyday decisions. They influence the taste of our food and the ambiance of our surroundings. Our sense of smell allows us to do more than just perceive odors. It shapes how we connect with the world and our past, impacting our emotions, memories, and social behavior.

Olfaction

Our sense of smell, also known as olfaction, results from the detection of airborne chemical odorants [1]. The ends of olfactory neurons in the nose contain hairlike extensions called cilia, where the nose's specialized odorant receptors are found. From the nose, these signals are transmitted to the olfactory cortex and other parts of the brain [1]. Similar to how natural light is created from a mixture of wavelengths, natural odors are the result of a combination of different odorant molecules [2]. For example, the odorant benzaldehyde produces an almond smell and vanillin produces a vanilla smell. However, scents often arrive in combination with one another. Think of a freshly baked almond croissant. You would smell a sweet mixture of vanilla and almond scents paired with the butter and dough, deciphering a unique combination of odorant molecules. The olfactory epithelium, located in the nasal cavity, has about 10 million olfactory receptor neurons (ORNs), each specialized to bind to a specific odorant molecule [2]. These ORNs transduce odorant identity into olfactory information that the brain then uses to determine the identity of a given scent. With about 350 types of ORNs, humans can discriminate up to one trillion odors [2].

Along with olfactory memory, there are several other categorizations of sensory memory, such as muscular, visual, and auditory [3]. Olfactory memory is unique, as it is retained for longer compared to other senses [4]. You may not exactly remember what your mom's oven looked like, but you could probably pinpoint the scent of her freshly baked cookies. In fact, studies demonstrate that most odor-cued memories are linked with the first decade of life, whereas memories associated with verbal and visual cues peak in early adulthood [5].

Olfaction connects directly to the brain's emotional and memory centers. All other senses are first processed at the thalamus, a brain structure involved in sensory and motor processing, before being relayed to higher brain structures for further processing [6]. Because our sense of smell goes straight to other structures such as the hippocampus and amygdala, olfaction is directly linked to emotions, social behavior, and memory [7]. This connection is facilitated by the olfactory nerve's connectivity to the amygdala and hippocampus, which are both largely involved in emotional and long-term memory [3]. The olfactory nerve is closely connected to these structures: only two synapses, or neuron connections, away from the amygdala and only three away from the hippocampus [3].

“Because our sense of smell goes straight to other structures such as the hippocampus and amygdala, olfaction is directly linked to emotions, social behavior, and memory [7].”

Emotion

Because olfaction both bypasses the thalamus and has close neuronal connections to the amygdala and hippocampus, it is heavily intertwined with emotion. Some suggest the connection between smell and emotion is a product of learning and memory. For example, food preferences could be influenced by a mother's diet during pregnancy, or one might form a negative association with eugenol, a substance used in dental fillings, after treating a cavity. Human and animal studies show that odors can evoke autonomic responses, such as the fight or flight response, along with emotions via pathways to the amygdala [8]. These signals travel to the hippocampus and become part of memory [8].

One instance in which odor elicits emotional distress is the case of post-traumatic stress disorder (PTSD) patients [9]. It is clinically recognized that unexpected intrusive smells can significantly impact individuals with PTSD, leading to the involuntary recall of odor memories. The olfactory cortex is crucial in emotional processing, and clinical observations confirm that odor-evoked memories are influential in PTSD symptomatology. Specific trauma-related smells, such as blood, napalm, and diesel, have been identified as triggers for anxiety and fear-related memories in PTSD patients. Intrusive reliving, a core symptom of PTSD, is traditionally linked to classical fear conditioning mechanisms, in which a person or animal negatively associates a stimulus with an event. In fear conditioning, a life-threatening situation activates the limbic system, which is a network of brain structures involved in processing memories and emotions. Then, these external cues become associated with arousal or anxiety. When these cues are later encountered, they can re-trigger that fear response. For instance, a study on 100 refugees in a psychiatric clinic revealed that 45% had experienced olfactory-triggered panic attacks in the previous month, with 58% reporting instances of intrusive reliving during such attacks [9].

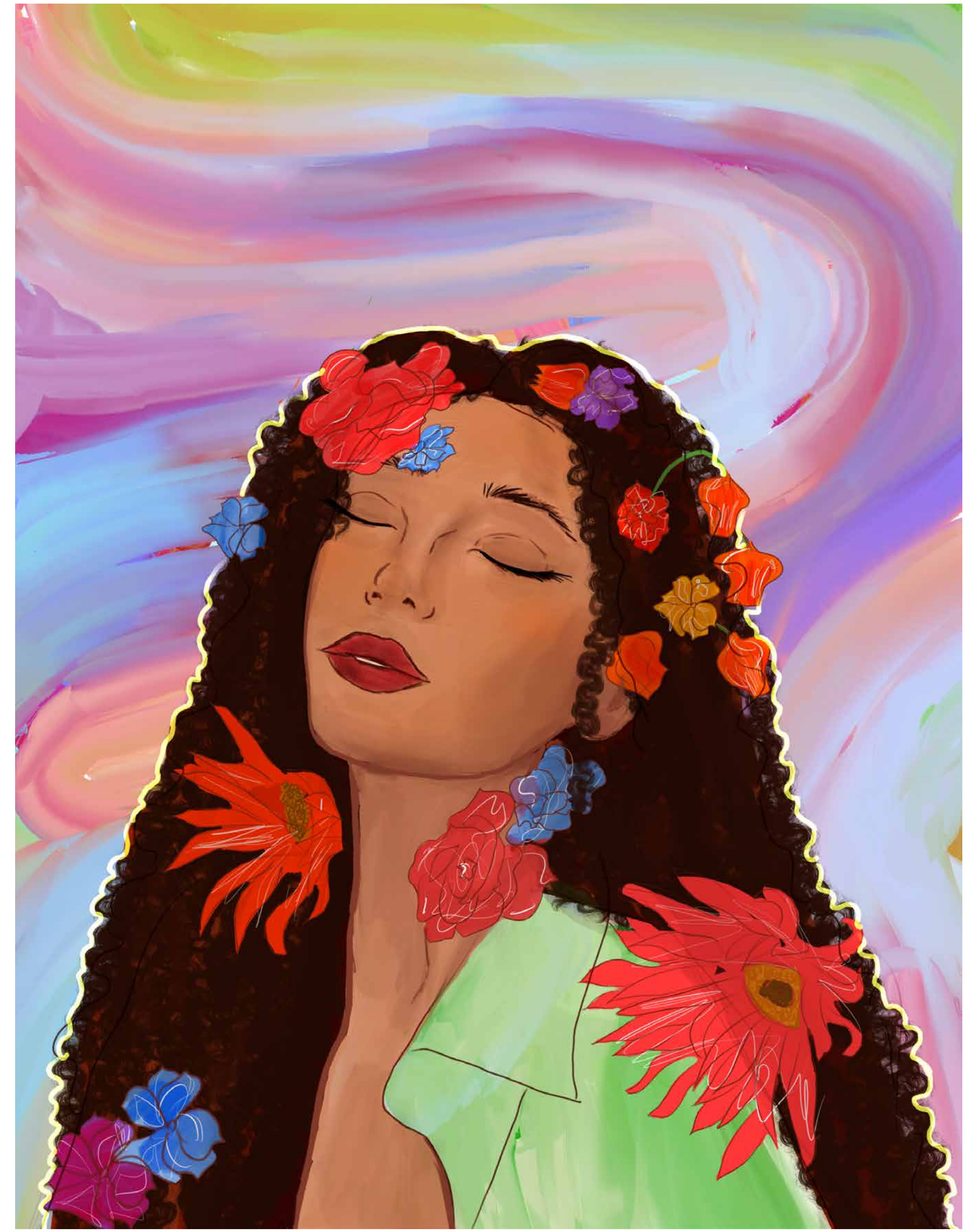
Odor can also elicit positive emotions such as reductions in anxiety and depression levels. A study by Ballanger et al. showed that odors such as lavender, citrus scents, and green leaf odors possess anxiety-reducing properties [10]. These effects are thought to be mediated through mechanisms similar to those of pharmacological treatments. For instance, in studies with animals, exposure to the scent of lavender has been shown to alter the signaling of GABA receptors, which ultimately inhibits brain activity. This exposure has also been shown to alter serotonergic signaling, playing a crucial role in mood regulation. Both of these signaling pathways are targets of pharmacological medications aimed at reducing anxiety. Additionally, green leaf odor has been found to produce anti-depressive effects in mice, partly by elevating serotonin levels. This mechanism is similar to that of certain antidepressants like selective serotonin reuptake inhibitors [10]. However, it is important to note that many of these studies use a no-odor control, which limits the ability to directly compare the effectiveness of different odors in inducing these effects [11].

Lastly, aromatherapy, the use of essential oils for therapeutic benefit, has been shown to reduce pain in various contexts. A meta-analysis conducted by Lakhan et al. found that aromatherapy significantly reduced pain, particularly in post-surgery and gynecological settings [12]. The majority of studies indicated that with the use of aromatherapy, patient satisfaction was increased, while patient anxiety and depression were decreased [12]. Furthermore, a randomized trial performed by Tanvisut et al. reported significant reductions in labor pain and duration along with a decreased need for painkillers following the use of aromatherapy [13]. Despite several studies in favor of aromatherapy, research is still limited. In a study done by Tang and Tse, there was only a slight reduction in pain among older adults treated with aromatherapy [14]. This suggests that the effectiveness of aromatherapy varies across populations and contexts, and more research needs to be done to truly determine its effectiveness as a pain reduction tool [14].

Reminiscence

I associate many scents with childhood, and chances are, you do too! When I think back to the scents of my childhood, several examples come to mind. I can easily recall the Scholastic book fair, where they had chocolate-scented calculators and banana scratch-and-sniff stickers. Another distinct memory is of my dad's green, minty deodorant, which my sister accidentally licked when we were kids. While it is unlikely that everyone shares these particular scent memories, many people can remember specific scents of their childhood.

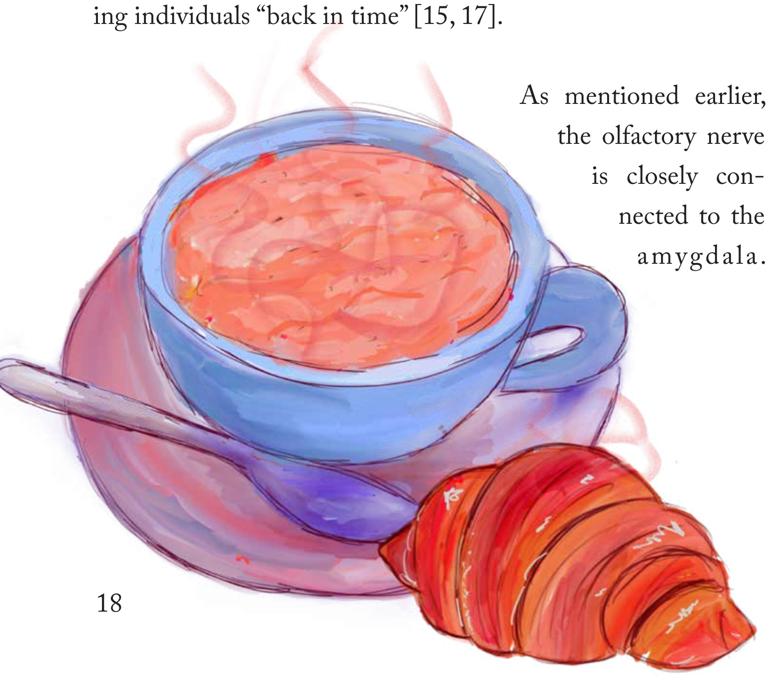
Nostalgia is a complex emotional state that combines elements of both happiness and sadness, often triggered by sensory experiences that remind individuals of significant moments in their past [15]. Among these sensory triggers, scents have a powerful ability to evoke nostalgia. This phenomenon was named the "Proust Phenomenon" after the French writer Marcel Proust, who documented that he was vividly reminded of his childhood memories upon smelling the aroma of a tea-soaked cake [15].



A study by Petratou et al. revealed that certain scents, particularly those from childhood, are strongly linked to emotions and memories [5]. In that study, bubblegum was found to be the most familiar and nostalgic scent, leading to increased self-esteem, social connection, optimism, and inspiration. They found that nostalgic scents can elicit strong feelings. For example, sweet odors are often associated with positive feelings, and heavier or stinkier odors cause negative reactions. This research supports the idea that childhood scents can trigger nostalgia, with some scents, such as bubblegum, being more effective than others [5].

This evidence aligns with the findings of Barrett et al., who observed that scents are remarkably effective nostalgia inducers compared to other sensory experiences, such as listening to music [16]. In their research, over half of the scents in both of their studies received nostalgia ratings at or above 2 on their scale (1 = not at all; 4 = very much). This is a stark contrast to studies using musical excerpts, where only about 26% of stimuli achieved similar nostalgia ratings. Moreover, scent-evoked nostalgia not only mirrors the emotional profile of music-evoked nostalgia but also generates greater positive emotion [15, 16].

Furthermore, research conducted by Rachel S. Herz demonstrated that scent-cued memories also contain more relevant details compared to memories triggered by visual or auditory cues [17]. In experiments where participants recalled memories using different sensory cues, those triggered by scents using oil-based beads were found to be more emotionally intense and detailed than those cued by visual or auditory stimuli. This suggests that scent-cued memories have a stronger connection to emotional and relevant details, and are more effective in bringing individuals "back in time" [15, 17].



As mentioned earlier, the olfactory nerve is closely connected to the amygdala.

Studies using positron emission tomography (PET), a useful non-invasive neuroimaging technique, have provided insight into why olfactory memories elicit strong emotional responses [5]. Imaging shows that compared to auditory or visual stimuli, olfactory cues achieve greater activation of the amygdala, a center for emotional processing. Additionally, when memories are cued by scents as opposed to words, there is a notable increase in activity within the limbic and temporal lobes, which are regions associated with positive memory processing [5].

Evolution and Attraction

Evolutionarily, olfaction has served to detect disease, injury, and unsafe foods. This ability has likely emerged as a protective mechanism. Humans have evolved to find sickness-related odors and rotted food pungent since being able to identify health-related issues in both ourselves and our food enhances our chances of survival [18].

Furthermore, olfaction has also played an evolutionary role in social relationships. A review done by Calvi et al. discusses humans' ability to recognize negative emotions (ie. fear, stress, or anxiety) through body odors, suggesting an evolutionary basis for this response [19]. They also discuss subsequent studies in which similar results were obtained for positive emotions (ie. sexual arousal and happiness). This suggests that people can unconsciously send messages to others through chemical signals in body odors [19].

While the term "pheromone" may be familiar, the evidence for the role of pheromones in human behavior is unclear and somewhat inconclusive, with small-scale studies yielding mixed results. There is some evidence for a possible human pheromone from breastfeeding mothers. During lactation, a substance is secreted from the mother's nipple. When put under the nose of a newborn, the baby responds with movements consistent with nursing behavior (eg. tongue protrusion, or lip pursing) [2]. This suggests that this substance may be a pheromone. Research is still being conducted on the existence of human pheromones. So, unfortunately, those pheromone perfumes you see on Amazon are not quite backed by science ... yet [2].

Instead of the commonly misused word pheromone, the concept of a chemosensory signal can be utilized in reference to smell communication in humans. Several studies have been conducted to test how these chemosensory signals influence behavior. One study shows that heterosexual men prefer the

scent of women while they are in the fertile phase of their menstrual cycle, and this effect dissipates when women use contraceptives [20]. This reveals that body odors shape physical attractiveness and can have an effect on the choice of partner.

Society

Smells influence every aspect of society, from our food to our clothes to the physical spaces we are in. The aroma of food connects us with our familial and cultural memories. This connection between smell and the body can also be applied in the context of clothing. Due to the close relationship between the body and clothing as well as the ability of clothing fibers to retain scents, odors linked to the body or infused into clothing can trigger strong reactions [21].

Our perception of visual stimuli is deeply intertwined with our feelings and past experiences towards them [22]. Palmer and Schloss' ecological valence theory (EVT) suggests that color preferences are influenced by feelings toward associated items. If a color is linked to positive experiences, we tend to like it, whereas if it is associated with negative experiences/memories/feelings, we are likely to dislike it. This theory suggests that our preferences guide us towards beneficial objects and away from harmful ones. Schloss et al. sought to determine whether this visual theory could be extended to smells. Recent findings indicate that preferences for familiar odors are shaped by collective feelings toward all associated items. For instance, the scent of apples is welcomed due to its connection with positive items like pie, soap, and candy, while fish odor is disliked because it is associated with negative things like dead fish and trash. This approach, known as odor WAVEs (weighted affective valence estimates), more accurately predicts smell preferences than just considering the namesake object. It suggests that preferences for smells are a summary of past experiences with those smells, influencing choices toward beneficial situations and away from harmful ones [22]. This could explain why some people may be drawn to smells that many find unpleasant, such as the scent of gasoline. Our individual experiences with different scents shape how we perceive them. While some people might associate the scent of gasoline with pleasant boat days, others might associate it with the anxiety of being on the road or traumatic experiences like car crashes.

Because smells are so intertwined with our environment and our emotions, they also often influence social dynamics. For example, a study by Qian Hui Tan found that the scent of cigarette smoke was polarizing, contributing to physical and social segregation between smokers and non-smokers in public places in Singapore [23]. However, scents of physical spaces can also be used advantageously. Companies use the connection between smell and memories to create more positive experiences for their consumers. A notable example of this was when the food company McCain used interactive advertising to emit the smell of baked potatoes at bus stops during the cold month of February. A more common example is hotel lobbies using certain fragrances to "scent brand" their hotels [24].

Conclusion

Olfaction weaves itself into many parts of our lives, shaping our experiences, memories, and social interactions. From its ability to trigger the nostalgic recall of childhood memories, like the unique scent of a childhood toy or a parent's cologne, to its role in evoking emotions and influencing behaviors, our sense of smell does more than just perceive odors. Scents can spark positive neurological reactions such as pain relief during childbirth or for negative emotions as in the case of individuals afflicted with PTSD. The scientific study of olfaction is an ongoing pursuit, with a real potential to open doors for future therapeutic interventions. ♛

Flattery to the Rescue

by Haley Herbert
art by Yixin Jia

Fight, Flight, Freeze, *Fawn*?

Picture this: you are out hiking in the woods with your friends when, suddenly, a bear stops you in your tracks. What would your initial reaction be? Do you run, fight back, or find yourself frozen in place? When in immediate danger, many people are aware of the three key reactions: fight, flight, and freeze. The basic fight or flight reaction consists of the urge to fight back or flee in response to a threat. Freezing occurs when a person's reaction is to remain in place. All of these reactions have complex neurobiological bases rooted in early survival mechanisms. But what happens when these systems are altered in some way? The fawn response is the tendency to use social appeasement as a means to minimize risk. When aggression or flight are not viable solutions, fawning can be used to maximize chances of survival. Fawning, in comparison to the other threat responses, may be a learned reaction following trauma.

Disrupting the Norm: Fear Responses After Trauma

Fight, flight, and freeze reactions are easier to distinguish when discussing an immediate threat to safety or connectedness, like our hiking example. However, there are many scenarios where these basic reactions can go awry. For instance, repeated traumatic experiences put individuals at risk for dysregulation of the threat response systems.

For diagnosing mental health disorders, including those encompassing trauma, the United States typically uses the Diagnostic and Statistical Manual (DSM), currently in its fifth edition. However, the International Classification of Diseases (ICD), currently in its eleventh edition, is used in other parts of the world [1]. The ICD provides further subclassification for chronic experiences of trauma that the DSM lacks. Because of this, this article focuses on classifications from the ICD rather than the DSM.

These repeated traumatic experiences are connected to a particular diagnosis in the ICD-11: complex PTSD (c-PTSD). Rather than just one traumatic trigger event, c-PTSD is characterized by repeated, inescapable traumas [1]. As an example, Sam is a hypothetical child who has undergone extensive childhood maltreatment, including abuse and neglect. Because of their background and their current lived experiences, Sam has been diagnosed by a licensed therapist with c-PTSD. Sam fits all of the basic criteria for c-PTSD, including reliving the emotional experiences of trauma. These symptoms manifest as chronic nightmares, avoidance symptoms, such as feeling disconnected from their peers, and hyperarousal or increased sensitivity to loud noises and startles. They often feel numb or irritable, which is indicative of affect dysregulation. Sam also has a negative self-concept, disclosing to their therapist that they feel a great sense of shame about their childhood and often feel worthless. Lastly, they have difficulty trusting people when making new friends, creating interpersonal difficulties in their life. Affect dysregulation, negative self-concept, and difficulty in relationships are three key diagnostic symptoms of c-PTSD, leading to Sam's diagnosis [1].

> *"People move back and forth between these stages every day, climbing up and down the ladder depending on their perception of danger at any given point."*

c-PTSD manifests as a result of atypical fear response symptoms [2]. Hyperarousal symptoms include experiences such as difficulty sleeping and concentrating, irritability, and hypervigilance, or a greater awareness of and reaction to fear-inducing stimuli. Hypervigilance can be thought of as an overactivation of the fight/flight systems, where people with c-PTSD are hyper-responsive and aware of incoming stimuli [2]. Repeatedly activating the threat response network leads to heightened reactivity within the brain's fear response network. Thus, the neural system becomes overly responsive to threats in order to detect and manage events similar to those that created the original traumas.

In c-PTSD, the threat response system is in overdrive. When presented with an everyday startle, such as a loud noise, Sam's response may be dramatic and pronounced. This increased sensitivity is also linked with emotional dysregulation, such as the irritability that Sam is experiencing [3]. Ultimately, traumatic experiences alter threat response systems.

What is Fawning?

Although the fight, flight, and freeze response systems encompass bodily reactions, recent research has explored a framework involving social interaction. Fawning is the use of social appeasement mechanisms to de-escalate a situation [4]. People who fawn are attempting to establish a sense of safety by mirroring what is expected and desired of them. While many people naturally engage in people-pleasing mechanisms, fawning occurs when a person feels a sense of danger [4]. While a person might feel the need to appease someone that they're close with during an everyday conversation about favorite television shows, musical artists, or even mutual friends, this would not be considered fawning because there is no perceived threat. Appeasement is a de-escalation process in which a trapped victim under serious threat attempts to socially appease their abusers [4]. This mechanism is used in situations where hostile defense and aggression—reactions we typically associate with fight/flight reactions—would be impossible or unbeneficial. In these situations, victims have essentially been forced to accept their situation but are, sometimes involuntarily, attempting to minimize their risk [5]. Fawning can range from lower-scale cognitive mechanisms such as feeling genuine fear and submission toward dominant individuals and reacting accordingly to more complex and conscious cognitive processes to feign submission [5].

Fawning often presents in those who have experienced interpersonal trauma. Chronic interpersonal trauma may result in a dysfunctional framework of relationships, especially when this trauma occurs during key developmental years [6]. Let's return to our earlier example of Sam, a hypothetical child who has experienced chronic maltreatment. When in active danger, Sam may attempt to fawn or "appease" their caregivers to minimize the abuse that they experience. Even years after the developmental abuse has occurred, appeasement has been found as a reaction among abuse victims [6]. Fawning may be critical to understanding how people who have experienced chronic interpersonal trauma are able to get through these situations and why these reactions may persist once the threat is gone.

Neurobiology of Fight/Flight/Freeze

Each of these reactions can be considered an innate survival mechanism. Many different models have been proposed to understand the neural bases of these threat responses. The polyvagal theory posits that there is a fundamental drive for a sense of safety and that the nervous system has a cascaded, hierarchical system to achieve it, which is largely centered around the vagus nerve [7]. The vagus nerve is the largest of the nerves that pass through the brain and consists of mostly sensory fibers [7, 8]. The autonomic nervous system (ANS) is a part of the body that carries messages to the brain and spinal cord and controls

physiological processes including heart rate, blood pressure, digestion, and sexual arousal [9]. According to the polyvagal theory, threat reactions can be split into three stages rooted in the development of the ANS and reactions of the vagus nerve that are associated with different behavioral responses [10].

The first of these stages is known as the social communication stage. It is the most developed stage, associated with mammalian development, and is responsible for social engagement [10]. The vagus nerve is connected to other cranial nerves that are largely responsible for facial expression and vocalization, both of which are core components for social engagement [7, 11]. Eventually, mammals evolved to produce a biological coating around their nerves, which increased the speed of signal transmission and facilitated faster social responses via the vagus nerve [7]. It is believed that mammals developed this ability to encourage positive social behaviors, ultimately furthering procreation. The connection between the vagus nerve and components of social responses allows this stage to center around social interactions and feelings of connectedness.

The next stage is known as the mobilization stage. This stage is associated with fight or flight behaviors due to its activation of a subcomponent of the ANS, the sympathetic nervous system, resulting in increased heart rate and metabolic output [10]. This activation promotes mobilization and escape behaviors [7]. In this stage, once a threat is perceived, the body responds by preparing for action. Activating hormones such as adrenaline and noradrenaline are released, which trigger bodily responses like increasing heart rate [12]. Such a response either delivers more oxygen to muscles to increase energy supply or constricts blood vessels to minimize blood loss [12].

The final stage is known as the immobilization stage. This stage is responsible for immobilization behaviors such as freezing or fainting and is considered the most primitive stage [10]. This stage may be responsible for what we consider a "freeze" response, where the body attempts to conserve energy [10]. Evolutionarily, freezing is thought to minimize risk by minimizing detection [13]. In a predator-prey relationship, one can imagine freezing as beneficial in situations where the prey has detected their predator, but the predator is unaware of them. If the prey has not been detected, but they attempt to either flee or fight back, they may be drawing attention to themselves, ultimately increasing risk [13]. Freezing also allows time for an individual to appraise a situation, helping them to understand and evaluate the present threat [13]. Freezing is an organism's last attempt to achieve safety.

All of these stages work together to facilitate a sense of safety. These responses are ordered in a hierarchy, where higher-level reactions supersede the lower-level reactions [7]. However, when higher levels do not provide a sense of safety, the body returns to lower, more primitive responses [7]. In this way, the stages can be thought of as a ladder. When our safety needs are not met, we start at the bottom of the ladder: the immobilization stage. Once we begin to feel safer, we climb up the ladder to the mobilization stage. Finally, when we feel safe enough, we climb to the top of the ladder: the social communication stage. We remain here until something in our environment shifts our perception of safety. When the mechanisms at the social communication stage fail to keep us safe, we move down to more primitive stages until we can establish this sense of safety. People move back and forth between these stages every day, climbing up and down the ladder depending on their perception of danger at any given point.

While some scientific critiques exist of the specific neural mechanisms behind these reactions, the broader idea of structural cascades is not subjected to these same criticisms and is critical to understanding human responses to threats [7, 14].

Thinking of these self-preservation responses in practice, let's apply this to a more tangible example. Imagine you are a high schooler having an enthusiastic conversation with your family at the dinner table. Here, you are starting in the social communication stage, feeling socially connected and engaged. All of a sudden, your family brings up your latest report card. You struggled immensely in school this term, and your family is deeply disappointed. Suddenly, your sense of social connection begins to fall away, and you begin to fear punishment. Your heart rate begins to speed up and you start breathing faster. The dinner table no longer feels safe and you are feeling the urge to leave the conversation. Now, you have entered the mobilization stage. Eventually, your parents decide to issue a punishment: a one-week grounding from seeing your friends. Upon hearing the news, you retreat to your room, alone, feeling upset and knowing that you cannot fight back against your parents' rules. At this point, you have entered the immobilization stage. We move through the three stages of the polyvagal theory every day, consistently assessing stressors and threats and reacting accordingly.

Neurobiology of Fawning

When presented with a threat, the initial response is to fall into the second stage of the polyvagal theory, the mobilization stage associated with fight/flight behaviors. However, in the case of appeasement, similar to freezing, escape is viewed as impossible. Normally, a system would then fall to the third stage, the immobilization stage. However, this is not the case with fawning. In these cases, fawning is considered a special activation strategy where both the fight/flight systems and the social engagement systems are activated. Returning to the ladder example, individuals engaging in a fawn response are caught in between stages, keeping one hand on the rung of social engagement and one foot on the rung of mobilization behaviors.

> "...fawning is considered a special activation strategy where both the fight/flight systems and the social engagement systems are activated."

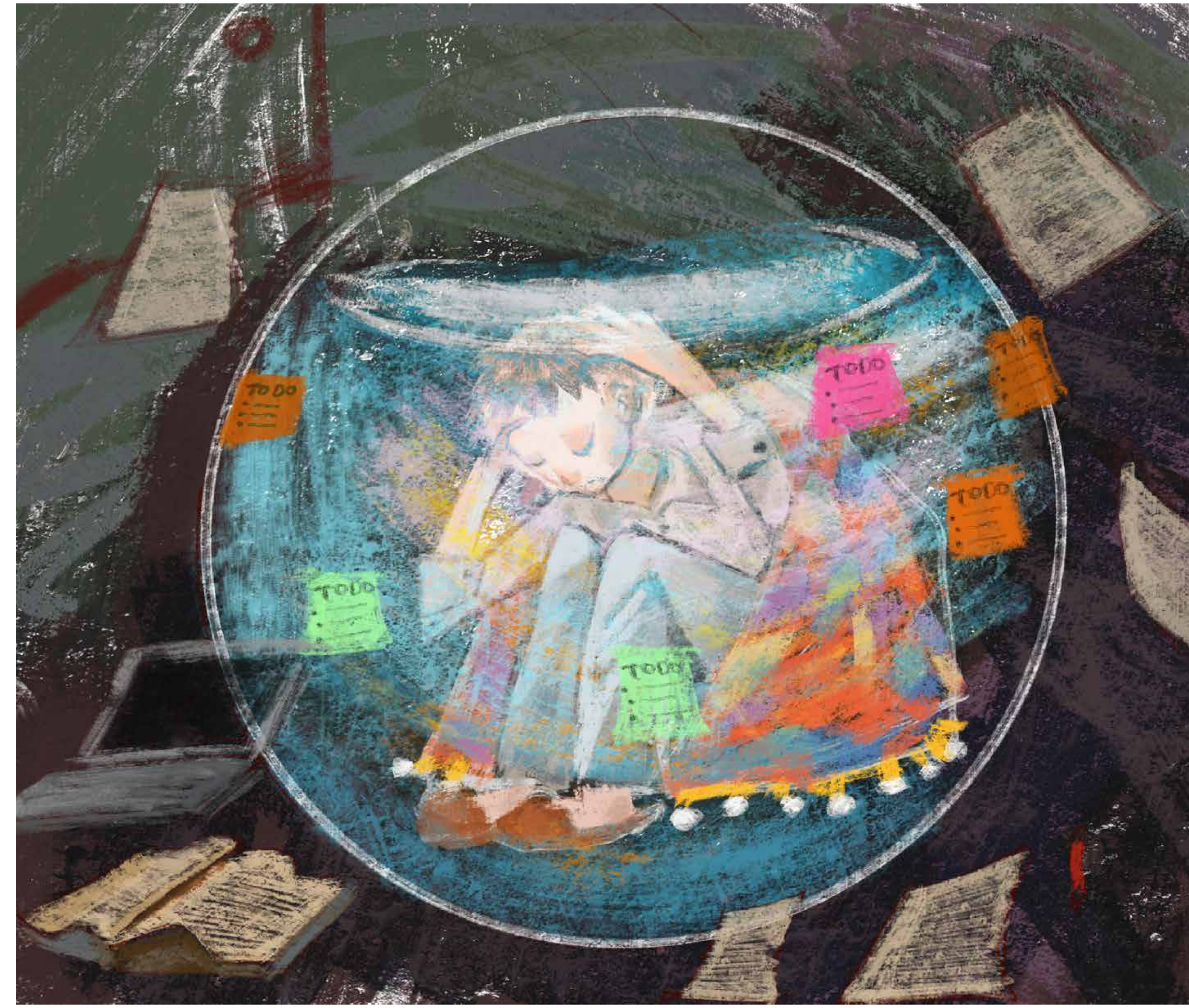
The social engagement system, in these cases, is also responsible for automatically activating the ventral vagus nerve, responsible for key social communication, to turn off fight/flight social cues and appear calm [4].

Let's return to the example of a high schooler being confronted about bad grades at the dinner table. Instead of our original example, let's consider Sam, our hypothetical child who has experienced chronic maltreatment. At this point, Sam has been put into an adoptive home. Sam, because of the interpersonal nature of their maltreatment, now engages in a fawn response instead of the standard fight, flight, and freeze responses. Under this framework, we start at the social communication stage. They feel connected to their new family and engaged in social conversation. Then, their family brings up the report card from the previous semester. Instead of immediately entering the fight or flight stage, they balance between the social communication and the mobilization stage. They begin to talk to their adoptive parents, trying to minimize the situation and appease them. Rather than just accepting their responsibility for the situation and moving forward with their conversation, the child tries their best to appease their adoptive parents at the expense of themselves. They do not place boundaries, and overcommit themselves to work beyond reasonable amounts of time in the following semester. They do not feel secure in themselves and do not think that they are good enough. Here, chronic trauma has altered Sam's response to social interactions that appear as a threat. Sam has engaged in fawning due to the lack of perceived escape and abuse history.

Through the polyvagal theory and the stages that it proposes for social communication and fawning, we can see the potential neurobiological bases of fawning. There are many other scenarios other than Sam's that could set the stage for fawning reactions. After prolonged dysregulation of the systems responsible for threat response, fawning may be an adaptive response designed to minimize risk using prosocial mechanisms.

Implications for Treatment

There are several problems with the way that c-PTSD is currently treated. As there is not a current diagnostic label in the US for repeated traumatic experiences, c-PTSD is often treated with the same treatment mechanisms as PTSD [15]. Exposure-based treatments include imaginal exposures, where patients are asked to imagine and recount their trauma, eventually resulting in reduced physiological and mental arousal. Another



type of exposure-based treatment is in vivo exposure, where patients are asked to confront distress-inducing stimuli face-to-face [15]. Currently, exposure-based treatments are some of the most common treatments for PTSD, including c-PTSD [16]. However, research has shown that those with c-PTSD do not benefit from exposure-based treatments to the same degree as those with PTSD, suggesting that treatments need to be adaptive to the individuals they are meant to serve [16].

A common theory for this phenomenon is thought to arise from the uniquely interpersonal nature of c-PTSD. As a result, a better understanding of the fawn response and appeasement may facilitate better treatment for c-PTSD. Appeasement may be the source of the chronic interpersonal struggles found in some individuals experiencing c-PTSD, making it critical for creating more effective treatment mechanisms [5]. By addressing the fawn response and the interpersonal nature of a patient's trauma head-on, we could better address many of the interpersonal struggles that those with c-PTSD face. In order for research to be funded and conducted, c-PTSD needs to be recognized as an official diagnosis in the United States. Once this is accomplished, more research needs to be completed on specific mechanisms of appeasement, the fawn response, and its connection to the polyvagal theory, allowing for more effective treatments for c-PTSD. ♔

Chronicles of Cognition

by Ruqaiya Mithani
art by Caitlin O'Neil

I'd like to tell you a story. But this story isn't one you've heard before. There are no dragons or mermaids, no valiant main characters or love triangle tropes, and not a single fairy godmother in sight. There is magic, although not in any of the typical wand-holding, Latin spellbook-invoking ways. The magic in *this* story lies in the transformative power of words.

Stories imprint on our minds from a young age – as much as we interact with them, they interact with us too. They change the way we think and process information and these changes remain embedded in our brain circuitry long after we mature. These tales, rooted in the most absurd imaginary characters, dreams of the future, and the mysteries of natural phenomena, are essential to our growth. The stories we encounter in our primary years give us our first tools for processing our own lives and even resurface as we transition to the professional world in industries like communications, education, and medicine.

Once Upon a Time

A long, long time ago, in a land far, far away known as your childhood, there began a story. Despite the generational, cultural, and structural differences in the stories we associate with our adolescence, they all accomplish a common goal: stories are a means of sharing information. Stories are always trying to tell us something and our brains are able to encode the information we hear as if it were something we watched happen in front of us. A study seeking to understand the mechanisms for memory recall specifically relating to stories found that participants who heard stories and those who watched them had activated similar areas in the brain when experiencing them, encoding them to memory, and recalling their memory [1]. This finding demonstrates that despite the difference in mode of transmission, individuals were able to process stories they heard as if they had experienced them themselves. In applying this theory to our own experiences, even if you only read or were told a story about a girl walking down a yellow brick road meeting a scarecrow and tin man, your brain would remember it in the same way it would if you had watched it happen.

In adolescence, we are told stories at every opportunity presented to us: before bed, at school, at the movies, and even at family barbecues. While the details of these stories invariably differ, they are powerful tools for learning about our world. So whether you have heard them while gathered around a sputtering campfire, saw them flickering across a television screen, or read them from the pages of a worn old book, stories offer us the same powerful messages and sequences.

When we listen to or read stories as children, our brains recognize and discern patterns to help us process information more effectively, using the structure of the story to guide our listening [2, 3]. This is called sequence learning and is one of the primary methods that the human brain uses to make predictions and decisions [4]. During sequence learning, the brain uses patterns it has learned from past experiences to make predictions

> *"As we continue to stack up personal experiences, our repertoire of patterns updates to register the new information we learned."*

about the next item in the sequence [4]. Several mechanisms such as chunking information, where related items are grouped together and thought of as that group in other contexts, and creating transition and time rules, where the brain learns how to approximate the time between items and the order of those items in sequences are employed by the brain to carry out these sequence learning processes [4, 5]. These processes activate several brain structures associated with memory formation, reward processing, and emotional behaviors, and allow the brain to not only *learn* the information but then apply it to make predictions when these sequences reoccur [4]. In the context of stories, sequence learning is the reason why we can not only recognize tropes like "enemies to lovers" or the "chosen one," but anticipate how situations will play out without knowing the exact ending [2]. Because we've seen similar patterns before, an uptight and aloof protagonist suddenly being forced to share an office with her sworn enemy is a sure sign that romance is brewing.

Equipped with the patterns we've cataloged through sequence learning, we can use reinforcement learning to update this information. Reinforcement learning utilizes both the environment and our past experiences and beliefs to make better decisions in the future thus demonstrating how our brains are continually updating our belief-based structures [4, 6]. For example, after studying for an exam all day and night, we may expect to get a perfect score like Elle Woods did on her LSATs. But when we receive a barely passing C-, our brain updates our expectations and the sequence from which those expectations came and may cause us to change our study habits in the future. In environments that are associated with rewards, the brain further updates patterns so we can make decisions based on the risks we may encounter and what may give us the greatest return [4, 7, 8]. After learning that getting a perfect score was not as easy for us compared to Elle, our brains might weigh the risks and rewards associated with cheating to get the score we want.

With the repetition of stories and overlapping messages, young brains begin to construct sequences and structures to predict what happens next within a new story through sequence learning. As we continue to stack up personal experiences, our repertoire of patterns updates to register the new information we learned. Eventually, we come to the point where we then utilize these patterns to comprehend the world around us. So while true love in childhood fairytales might be decided by the fit of a glass slipper, as we grow and try to find love for ourselves, we learn that love is so much more complicated than Prince Charming coming to the rescue.

You're All Grown Up Now

So far we have seen how stories engage with our brains in childhood, generating the basis for what we know about the human experience. Perhaps surprisingly, though, stories remain useful to us well into adulthood – they are significantly helpful in developing an understanding of our adult selves and our lives. Adult educator Marsha Rossiter posits that as humans, we understand our own lives in narratives, whether that be one large, continuous story or narrative episodes [9]. Narratives are particularly useful here because they allow us to ascribe meaning to our experiences [9, 10]. The stories we once read as children follow clear plotlines that teach easily-understood morals, like the familiar story of a little boy lying repeatedly about seeing a wolf and then being unable to get help when he really needed it, an illustration of the importance of telling the truth. Therefore, thinking of our own lives as a series of connected events allows us to extrapolate meaning from them compared to if we processed them disjointedly.

American psychologist Jerome Bruner offers more insight into this phenomenon. Bruner explains that stories activate a double landscape of narration: a landscape of action and a landscape of consciousness [11]. The "landscape of action" is the dimension of the story where its own events happen: the protagonist leaves home, the happy couple has a major argument, the guy gets the girl—typical plot events. But the "landscape of consciousness" is the space where the character's world comes into play: the protagonist feels smothered at home and wants to discover themself, the couple argues because they want to resolve problems. This landscape gives us as readers a chance to interact more deeply with the story through the characters' thoughts, beliefs, and motivations [11]. Stories resemble simulations that give the audience direct access to things they wouldn't be able to observe otherwise, such as the mental states and feelings of others [12]. Through these simulations, readers are able to understand and eventually predict complex social relationships in the real world. Dialogues, conflicts, and resolutions between characters give us insight into their behaviors. They enable us to take on their perspective and eventually help us develop a sense of empathy for and connection to them as if we were experiencing their strife ourselves [9, 13].

Much of the neurological breakdown of stories is based in a network centered around the prefrontal cortex – a brain region responsible for regulating most of our thoughts, emotions, and behaviors [14]. The prefrontal cortex is also where we process what is happening in our surroundings and compare it to previous experiences [15]. A study using BOLD fMRI, a brain imaging technique that measures blood oxygenation levels in the brain as a proxy for activity levels in certain regions, found that this area of the brain is activated not only when someone is listening to a story but also when they are telling one [16]. Activation in the prefrontal cortex is associated with Theory of Mind (ToM), or the process and ability to predict, explain, and describe behavior by assigning mental states to oneself and others [17]. ToM here occurs in two different ways. Listeners activate this network when they position themselves to make inferences about a character's motives, emotions, and behaviors as well as the goals of the storyteller [16]. For the storyteller, the inferences made are less about the story itself since they already know its content and more about how their audience perceives the story [14]. Regardless of the actual story, we neurologically decipher relationships between characters, their environment, and our own connection to them in similar ways.

> *"Stories provide the same observational information as experiencing or viewing an action first-hand [21, 22]. Due to this similarity, the impact that stories have mirrors that of real-life experiences."*

In addition to developing ToM to grasp and apply broader themes from stories, storytelling also uses the mirror neuron system to enhance narrative salience. This system is activated when observing an action and performing it [18]. These neurons link the frontal and parietal lobes to the temporal lobe, forming a brain circuit [19]. The temporal lobe contains neurons that catalog the visual information of an action – how it looks as it's performed. This information is then processed and sent to the parietal mirror neurons to determine the physical aspects of the observed action. The frontal mirror neurons then code the information sent to translate the goal of the action. Overall, this sequence creates a link between the visuals of an observed action and its physical execution, enabling imitation [19]. A similar process unfolds when we experience a story. This is particularly true for visual stories, though auditory stories can also activate mirror neurons, as hearing about an action can evoke a memory of it [20]. Stories provide the same observational information as experiencing or viewing an action first-hand [21, 22]. Due to this similarity, the impact that stories have mirrors that of real-life experiences.

As adults, the stories we grew up hearing and the new ones we write ourselves all aid us in enhancing our own social cognitive abilities. We better understand how others think and subsequently relate to them better, building our own relationships using knowledge from stories. This setup is not only advantageous for us to communicate better person-to-person, but can be engineered for others to take advantage of as well.

The Mind Manipulated

The cognitive influence of stories opens up several avenues for them to be applied to new contexts and across multiple disciplines. For example, educators have begun using a technique known as "narrative science storytelling" where one takes advantage of the brain's existing affinity to the structure of stories to make science more accessible and engaging [23]. Scientists are being encouraged to leverage the emotional reaction that stories create to help generate more interest in scientific discoveries in a larger audience through the use of characters, drama, description, and a slew of other literary techniques [23]. Studies show that adding personal narratives about the struggles of famous scientists when presenting research led to a greater interest in science materials in a population of high school students [23, 24]. Students who struggled academically benefited the most from these narratives. Science felt more accessible and relatable, particularly for those who may doubt how their own capabilities measured against the expectations of STEM fields [23, 24]. By fitting scientific findings into the narrative structures of stories, researchers are able to break down complicated and often abstract information so that it can be understood and shared more widely.

The benefits of narrative science are also exemplified by narrative medicine. Although there is no generally accepted definition for this type of medicine, physician Rita Charon emphasizes that it lets medical practitioners "recognize, absorb, interpret, and be moved by the stories of illness" [25]. Using stories as an entry point, narrative-based medicine aims to make use of the storytelling structures we grew up with to make treatment more effective. Patients are urged to tell their own stories about their illnesses, humanizing them and helping them feel less like a burden [25]. This also allows doctors to add their own stories and further create a space that is both holistic and patient-centered, improving overall diagnoses and patient experiences [25, 26]. When applied to patients going through brain cancer treatments, researchers found that participants who underwent narrative medicine practices were able to renegotiate their identities and felt they were better able to acclimate to their new circumstances without losing their sense of self [27].

In other industries, however, the incorporation of storytelling may do more harm than good. In marketing, the rise of social media has led to the emergence of a new genre of advertising known as "narrative advertising" – deceptive ads designed to fit right into your social media feed [28]. Because these are not explicitly advertisements and are smoothly integrated alongside non-promoted content, companies can take advantage of storytelling to push their products and opinions. On apps like Instagram and TikTok, it is common to see content creators who make a living off their relatability and talking about their experiences with services, products, and businesses – however, these accounts are not always genuinely motivated since creators are able to receive commissions from the products they sell. When these ads are mixed into viewers' regular content feed, they may not seem financially motivated or like an advertisement at all. At first glance, videos explaining how a creator may have struggled with an issue all their life and finally found a product that worked may seem legitimate until the "commission paid" sign at the bottom calls the integrity of their narrative into question. However, this frequently goes unnoticed. The lack of required disclosure and ease of hiding financial motives creates an environment where creators and advertisers alike are able to exploit human sensitivity to stories and turn empathy into profit [28].

Stories have always had the ability to elicit emotional reactions. We laugh when a cop slips on a banana peel, cry when someone loses a loved one, become scared when a predator catches up to its prey, and empathize with a victim of bullying who finally speaks up. But too often we limit stories to just that: forms of entertainment and a source of nostalgic memories. In reality, though, stories are much more. In the earliest, most pivotal stages of our lives, stories shape the way we understand the world around us. Stories most definitely have the potential to shape how we interpret our surroundings and are *actively* doing so, right now! The way you look at the world and the connections you make between what you see and know are influenced by the frameworks established from the stories you've grown up with and continue to hear. Old stories make up the basic structure of our world-viewing lens, while new stories update this lens as we grow older and the world around us changes. While some uses of stories lend themselves to negative outcomes, their many positive applications are hard to ignore. Stories may be filled with kingdom-conquering fae, underdog uprisings, and billionaire mafia bosses, but are undeniably so much more. Stories are full of life – and life is simply a collection of stories. The difference? In life, you get to tell your own story.

Whispers of the Deep

by Laura Mittelman
art by Hailey Kopp

"Sperm whales live in an environment totally different from ours, one with completely different constraints. Where we are visual, they see the world through sound—both the sounds they hear and the sounds they make." (Whitehead, as cited in Wagner, 2011)

Have you ever wondered what it would be like to "see" the world through sound? I bet you can't quite imagine it because, unlike sperm whales, humans aren't equipped with echolocation—a sophisticated biological sonar system that grants sperm whales one of the most powerful acoustic signaling devices in the animal kingdom. Far from whispers, these sound waves are incredibly powerful, producing the highest sound pressure ever measured from an animal. This allows sperm whales to navigate the deep oceans, hunt prey, and communicate by listening for their echos [1, 2].

Within the realm of animal communication research, scientists have explored the nuanced language signals of spiders, pollinators, rodents, birds, primates, and cetaceans [3]. Amidst this diversity, cetaceans—whales, dolphins, and porpoises—exhibit a unique communicative complexity, demonstrating a wide array of essential social skills that parallel many of our own social and linguistic characteristics. Toothed whales, which include sperm whales, are among the few animals that possess the capacity for vocal production learning [3]. Their unique ability to integrate and reproduce novel sounds has allowed toothed whales to develop sound communication repertoires; and, the sophistication with which whales integrate this skill into their social world distinguishes them as an exemplary species of vocal production learning.

> *"The sophisticated arrangement of the sperm whale's biosonar system represents a case of remarkable evolutionary adaptation, which has enabled these gentle giants to navigate, communicate, and hunt the dark expanses of the ocean solely through echolocation."*

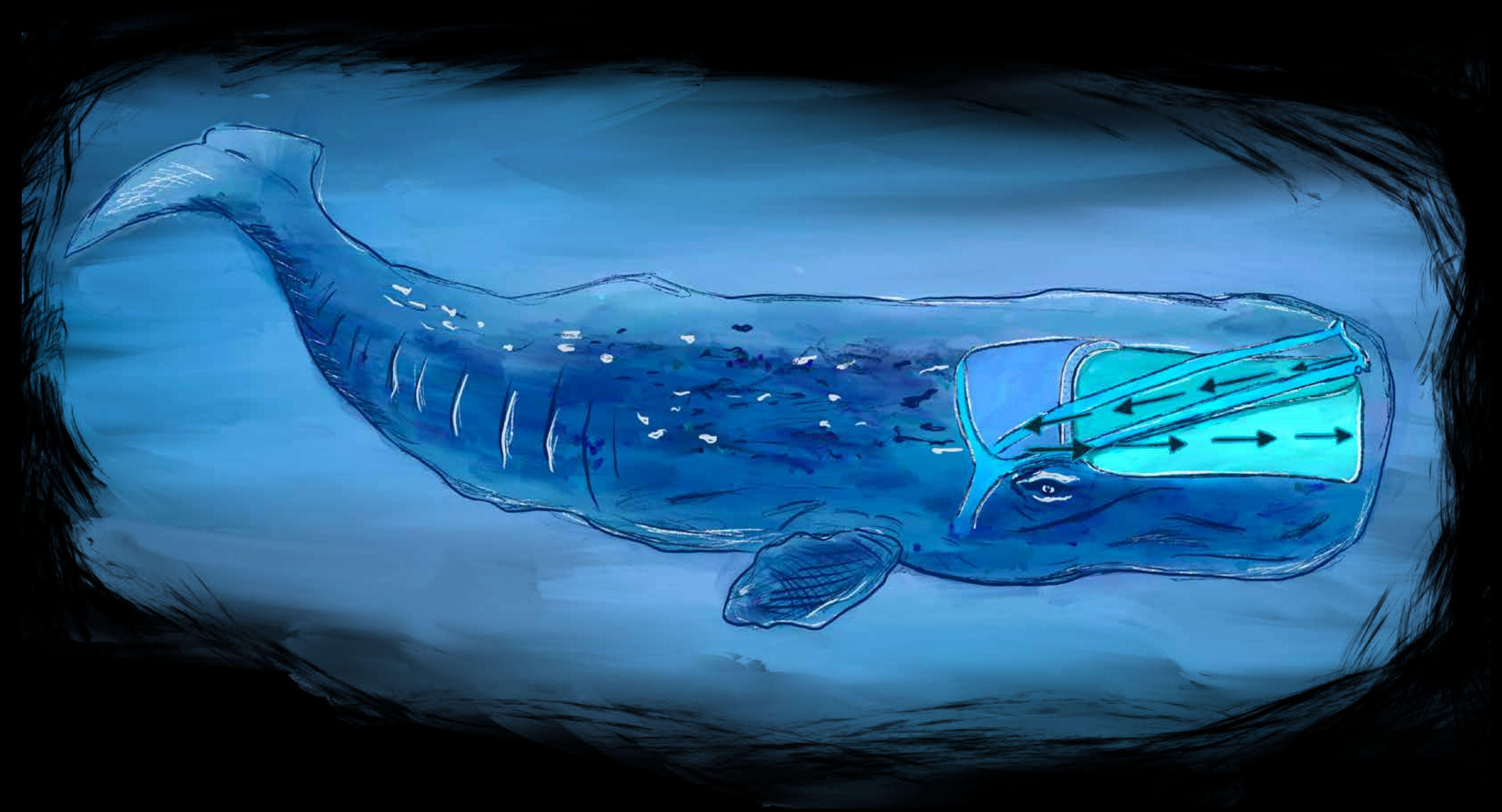
The one-of-a-kind social intelligence of whales has captured the intrigue of scientists, who are beginning, now more than ever, to unravel the threads of their social bonds and fleeting encounters, attributing certain communicative vocalizations to a dynamic structure of inter-whale relationships. Importantly, technological advancements in research innovations have been central to recent findings in the field. The logistical difficulties associated with the natural observation of marine life, especially whales, have proven to be a historical obstacle in the development of whale communication theory [3]. But thanks to modern technology and machine learning systems, a more profound understanding of non-human communication is forthcoming [3].

Neurobiology of the Bioacoustic System

"A sperm whale is to my fancy the most uncomely shaped animal that I can think of." (Ellsworth, 1990)

Have you ever marveled at the sight of whales gracefully navigating the ocean in pods, or considered their harmonious synchronization of movements? This captivating display is not just a random act of nature but a glimpse into the intricate social dynamics and familial structures of sperm whales. In fact, sperm whales have evolved to interact within a highly dynamic society, marked by long-lasting social relationships and frequent stranger interactions [3].

Sperm whales are born into closely bonded matrilineal families, where multiple females and their offspring travel together in a pod, making group decisions related to hunting and foraging [4, 5]. While pods are characterized by females and their young, male whales typically travel solo, breaking apart from their family pods around age five [6, 7]. Within family lineages, female sperm whales exhibit behaviors that provide a strong testament to their high-functioning sociability and commitment to family, such as collectively defending and raising their offspring [8]. For example, female whales will often nurse each others' calves, forming bonds that evolve into decade-long relationships [8]. Individual pods also come together to form clans—groups of hundreds, even tens of thousands of whales—with shared movement patterns, such as diving synchronization, coordinated foraging, and similar diets, crucial for the clans' survival [9]. Sperm whales exhibit diversity among these characteristics between clans, and despite overlapping ocean territory, clans remain socially segregated [3]. This resemblance of community building is remarkable for non-human species and speaks strongly to their advanced communication abilities.



To really appreciate and understand the awe-inspiring social architecture that spans the world's oceans, we must consider the neuroscience of sperm whales, which has amassed an impressive array of neurophysiological traits through 50 million years of aquatic evolution. After all, their fascinating social behavior, cognitive prowess, and sonar capabilities are direct reflections of their sophisticated brain structure [10].

The most profound neurophysiological development in sperm whales is their echolocation capacity, which allows them to navigate, detect objects, and communicate in a three-dimensional auditory world. Sperm whales also possess advanced auditory processing skills and communicative abilities, which ultimately allow for an advanced network of inter-whale socialization [10]. This unique combination of neurobiological features shapes their complex behavior and communication systems, making sperm whales highly cultural creatures, much like ourselves. Thus, when comparing the evolutionary routes of whales and human brain development, we can see a common path toward achieving neurobiological and cognitive sophistication in two completely distinct species in widely different habitats [11]. This parallelism is what captivates the fascination of scientists, motivating them to further study and develop our understanding of whale sociocultural dynamics.

Their brain—one of the largest brains of all animals on Earth—harnesses a rich neurological capacity, bestowing on sperm whales a sophisticated intellectual and social power [12, 13]. In fact, their brain is six times heavier than a human brain, with complex cerebral structures indicative of advanced cognition [14]. Much like our brain, which has different brain regions designated for specific functions, toothed whale brains exhibit similar segmentation. In fact, the toothed whale brain (which includes that of the sperm whale) surpasses the human brain in gyrification, the number of folds and convolutions on its surface [14]. Increased gyrification is associated with increased intelligence and cognitive ability in humans [15]. Therefore, although the brain circuitry of sperm whales differs significantly from that of humans, it is likely that their social and intellectual capacity is on a similar level to ours [14].

Zooming out to the overall head-to-body ratio of the sperm whale, their massive head—which houses not only their sophisticated brain but also their enormous nose—is a hallmark feature of sperm whales [16]. Claiming one-third of their entire body length and weight, you may be surprised to learn that their nasal complex is not designed to house a robust olfactory (smell) system [12]. Rather, their olfactory system is completely absent. In fact, the regression of the sperm whale olfactory system begins during the early fetal period of neurodevelopment, when the olfactory bulb (the main receiving center for sensory input relating to smell) and the olfactory nerve (which transmits smell information from the olfactory bulb to the brain) completely vanish [10]. However, despite the absence of smell, adult sperm whales are not left short of five senses. Echolocation, the biological sonar system used by whales to navigate, forage, and communicate via the production of sound waves and their echos, assumes the role of their fifth sense [12, 17]. Scientists have coined this phenomenon the echolocation priority hypothesis, which states that the evolutionary acquisition of echolocation in cetaceans catalyzed the reduction, or in the case of sperm whales, the complete disappearance of, the olfactory system [17, 18]. Thus, the evolution of echolocation and the sperm whale biosonar system illustrates a fascinating trade-off, where smell was sacrificed for the advanced ability to perceive their environment through sound.

The evolution of echolocation also allowed sperm whales to meet the specific sensory demands of the deep blue. They developed the ability to locate prey, communicate, and navigate within the darkness of the mesopelagic zone: the layer of ocean ranging from 200 to 1,000 meters below the surface, where sunlight is barely detectable [19, 20]. The evolution of such a powerful biosonar system epitomizes sperm whales as "animals of extremes" and enables them to produce the most powerful sounds in the animal kingdom [3, 4, 20]. In fact, their large head serves as the origin of their biological name: *Physeter macrocephalus–macrocephalus*, translating to "large head" [3]. Encased within their biosonar system are various interconnected biological structures, consisting of soft organs weaved within air sacs and nasal passages, all contributing to their remarkable sense of echolocation. Interestingly, the nasal cavity of sperm whales is asymmetrical, with the left side allotted for the respiratory system, and the right specialized for sound production [21].

Focusing on the right side, we find two of the sperm whale's most important soft organs: the 'spermaceti' and 'junk' organs. The spermaceti organ is a massive, cone-shaped structural sac in the nose filled with about 1,900 liters of oil, known as spermaceti oil—which was the once-prized oil harvested for making spermaceti candles and illuminating oils during the historical American whaling era [21, 22]. Behind the spermaceti organ, we find the frontal air sac. Together, these two structures — the spermaceti organ and the frontal air sac — work as an exceptional sound mirror within their nose [21]. At the foremost region of the spermaceti organ, a lipped structure of connective tissue forms the monkey lips, which produce sounds through a pneumatic process, much like human vocal cords [23, 24]. The second of the two organs is the junk organ, located below the spermaceti organ. Altogether, the junk and spermaceti organs, the surrounding air sacs and passageways, and the clapper system of the monkey lips make up the biosonar system, which allows for sound energy to focus into extremely powerful vocalizations [13, 21]. The sophisticated arrangement of the sperm whale's biosonar system represents a case of remarkable evolutionary adaptation, which has enabled these gentle giants to navigate, communicate, and hunt the dark expanses of the ocean solely through echolocation.

Acoustic Communication of Sperm Whales

"...if an animal spends all morning in non-productive socializing, he must be at least twice as efficient a producer in the afternoon." (Humphrey, 1976)

Though developed as a means to navigate the dark waters of the deep, sperm whales have adapted their bioacoustic system for complex, inter-whale communication. The sperm whale produces a distinctive brief acoustic signal that serves as the basis for all its vocalizations and is commonly referred to as a *click* [3]. Sometimes, but rarely, other vocalizations—*squeals* and *trumpets*—are made, but clicks serve as the primary linguistic mechanism for echolocation and communication in sperm whales [13]. Each click is constituted by a brief, highly directional, broadband soundwave, composed of an initial powerful pulse, and followed by additional pulses of decreasing amplitude [13]. Within the whale's nose, the spermaceti organ and its associated structures are responsible for generating a click [25].

The intricacies of the sperm whale's bioacoustic system have facilitated their survival through the usage of clicks for navigation and hunting. Yet, across evolution, clicks have transcended their evolutionary origin to weave the complex fabric of social bonds

> "...babbling [of young calves] reflects an immature language area in their brain, which matures as they grow, allowing them to gain cognitive sophistication and hone their call repertoire, much like humans."

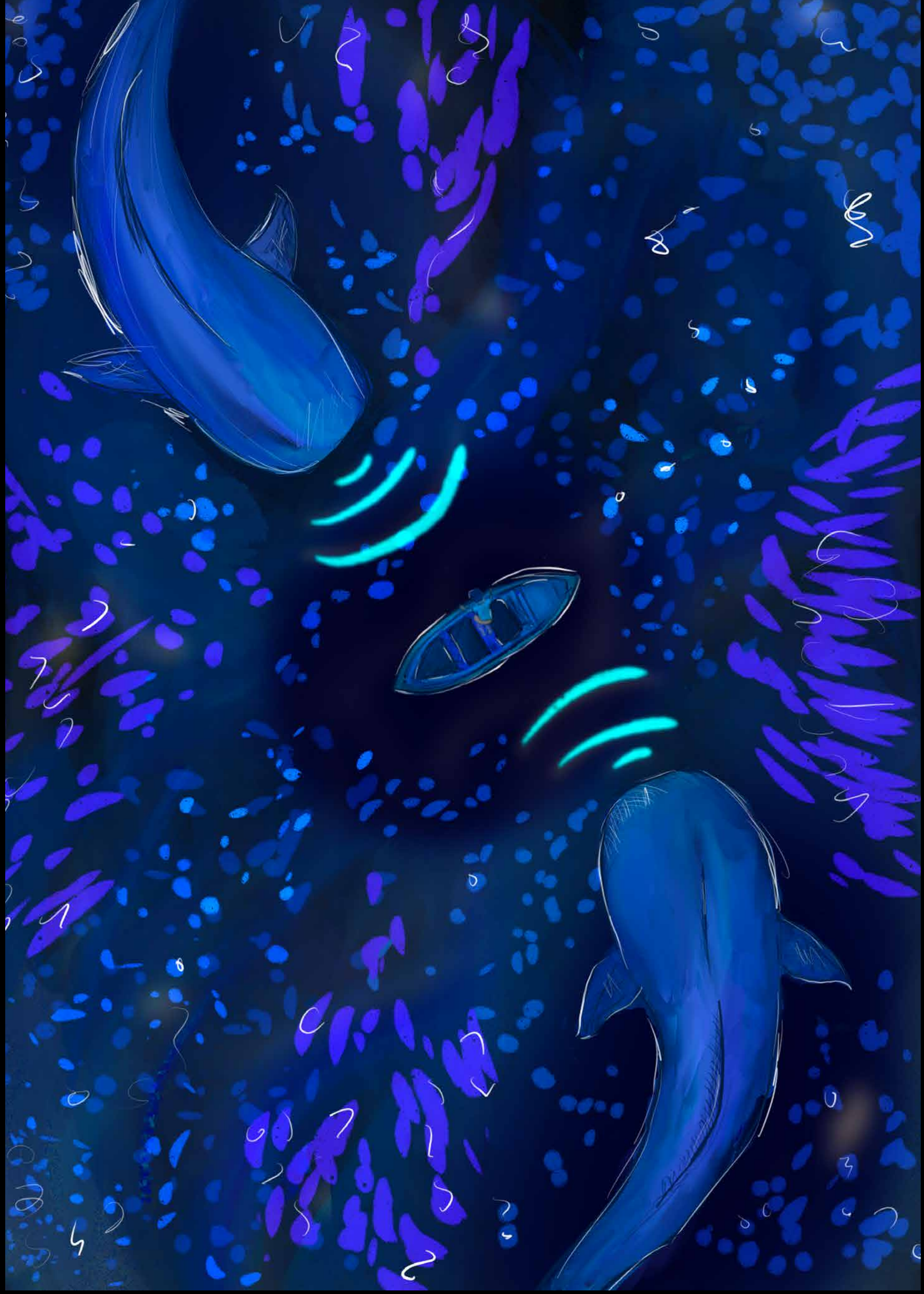
and societal structures among sperm whales. Clicks have even been established as the foundation of sperm whales' language system, much like the alphabets of human languages [16]. Sperm whale communication utilizes short bursts of clicks (less than 2 seconds each) as their basic language framework, stringing multiple clicks into a stereotyped pattern recognizable by other whales. Such patterns of clicks are termed codas and are typically made up of 2-40 clicks. Codas are comparable to words used in human languages, and each clan of sperm whales may have its unique usage of these codas for communication—termed dialect—which typically contains around 20 distinct coda types. Interestingly, different sperm whale dialects have been detected in different oceans, between the Pacific, Indian, and Atlantic [16]. And, on a more local level, individual whales of a specific family share a natal dialect of approximately 10 coda types, which provides insight into potential family-specific language acquisition patterns [26]. Researchers have also observed that codas appear to be rich in information about the caller's identity [3]. This would indicate that sperm whales can recognize each other, from great distances, by their individual clicks and codas. These findings might suggest that codas contain a certain depth of meaning that contributes greatly to the formation of whale societies, paralleling the sophisticated capabilities of human linguistics [3]. Furthermore, calves exhibit a learning curve in language production, much like young children, producing unrecognizable coda types ("babble") until around two years old, when they start developing a larger repertoire of call types [26]. As they mature, their call repertoire narrows to the codas produced only by their natal family [26]. These 'language' acquisition observations parallel the brain development of young calves: their babbling reflects an immature language area in their brain, which matures as they grow, allowing them to gain cognitive sophistication and hone their call repertoire, much like humans.

As we look deeper into the intricate symphony of codas that sperm whales engage in, we can reveal a fascinating glimpse into their advanced language system. Sperm whales exchange codas in harmonized patterns, between two or more whales at a time [27]. Within such a 'conversation,' there appears to be turn-taking between each whale's vocalizations, with response codas generated within 2 seconds of each other, sometimes overlapping and producing identical calls [27]. Remarkably, not only do these echolocation pulses travel close, within meters of nearby whales, but also travel kilometers, reaching whales far away [11, 13]. It may be wise, now, to reconsider calling these vocalizations "whispers of the deep," as they are incredibly powerful—the most powerful sound in the animal kingdom.

From the Ocean to Understanding

"The goal is to turn data into information, and information into insight." (Carly Fiorina, 2004)

You might be wondering how researchers have started to piece together this communication puzzle, which we are just beginning to truly understand while studying such an elusive and inaccessible (and breathtaking) species. The schematic of the sperm whale bioacoustic data collection process paints quite a complicated picture. With multiple data sources and several techniques of data acquisition, researchers must analyze and interweave these assets towards the goal of understanding the communication of sperm whales. Outlined simply, the data acquisition process involves researchers collecting a diverse range of data: social, video, environmental, behavioral, and audio [3]. The technology used to gather these data includes (1) aerial drones, which are used to survey large areas of ocean inhabited

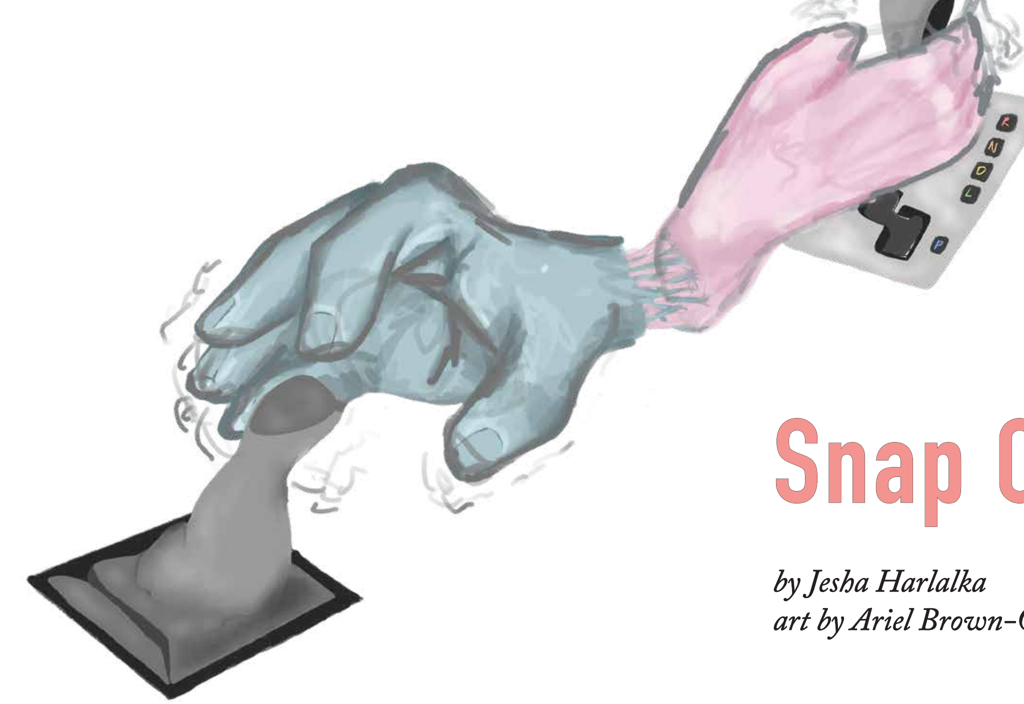


by sperm whales; (2) aquatic drones, also known as underwater robots and drifters, which collect audio and video recordings to analyze behavioral and communication patterns within a group of whales; (3) tethered buoy arrays, which record bioacoustic signals from several hundred meters below sea level, where sperm whales are known to hunt; and (4) tags, which are recording devices attached directly to whales [3]. Tags are the most innovative research device, providing highly detailed insight into daily behaviors and interactions between sperm whales, especially when associating activity patterns with bioacoustic recordings from tethered buoy arrays [28].

Researchers then take their observations and begin building a model to decode sperm whale communication. Let's first consider the human language, which has a hierarchically organized phonological structure: the smallest speech unit that changes the meaning of a word in our language is a phoneme, represented by alphabetical letters in the English language, as in *r*eef vs. *b*eef [29]. Our brains process phonemes according to their fundamental acoustic features in a brain area called the superior temporal gyrus (STG), also known as Wernicke's area [30]. In the sperm whale, researchers have conjectured that codas act as the fundamental communicative unit (like a *phoneme*) in a similar hierarchical language structure [3]. Therefore, researchers use machine learning techniques to determine how different coda types are distinguished from one another, if features of coda clicks carry any phonotactic rules, and if sperm whales utilize formal grammatical structures when communicating [3]. These questions have yet to be fully explored and are currently the driving force behind sperm whale communication projects.

Another pressing question researchers have: do any individual coda clicks carry information or functional meaning? To answer this question, researchers are interrogating the syntax and semantics of the bioacoustic recordings they collect. Considering human language once again, we have the capacity to produce complex sentences from basic units according to linguistic rules—the *syntax* of our language. By applying machine learning techniques, researchers hope to form further hypotheses about the hierarchical usage of codas for inter-whale vocalization—the syntax of sperm whale communication [3].

Overall, the key question concerns the *meaning* behind all sperm whale vocalizations. What are these magnificent creatures saying to each other? To answer this, researchers want to identify the minimal meaning-carrying unit of whale vocalizations—the *semantics* of whale communication. It is already known that individual, familial, and historical information is contained within individual codas, but the majority of recorded codas remain poorly understood, as well as the inherent differences between individual clicks and coda patterns [3, 26, 31]. Nevertheless, the quest to decode the sperm whale communication system is ongoing, and everyday researchers are getting closer to unraveling the sophisticated vocalizations of these awe-inspiring mammals. Amidst this intricate exploration, we can imagine a future where sperm whale conversations rise to the surface. ♔



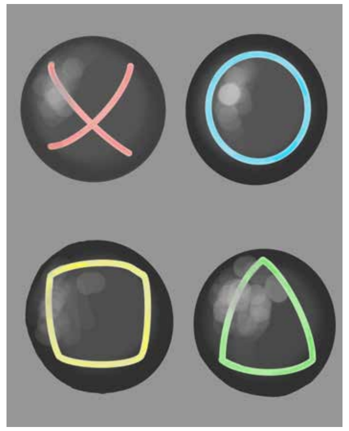
Snap Out of It!

by Jesha Harlalka
art by Ariel Brown-Ogha

The room is brightened with the sunrise, and your eyes fly open with the blaring sound of your alarm. Soon enough, you make your way through the bustling morning commute to your local cafe only to find that your usual—a blueberry muffin—is sold out. You're then forced to make a conscious decision: what would you like to order instead? Which other muffins are around the same price? Do any of them have ingredients that you are allergic to? Which one will taste good with your coffee? Typically, you do not need to think about these factors because you are ordering your usual, but now they are all things you need to consider. If you were ordering your usual muffin, it would have been an unconscious decision. You are said to be conscious when you are aware of sensations, feel emotions, form mental imagery, and experience overall higher cognitive functioning [1]. So in which situations do you switch from unconscious to conscious? What is the mechanism for this switch?

The shift from unconscious to conscious decision-making underscores the intricate nature of consciousness in our daily choices. To explain this difference in states, psychologists Tversky and Kahneman introduced the Dual Processing Model, which delineates two systems: System 1 and System 2 [2]. To better understand the differences between these systems, we will refer to System 1 as the 'Instinctive System' and System 2 as the 'Deliberate System.' System 1 is unconscious, fast, automatic, and intuitive, based on instincts and past experiences. On the other hand, System 2 is conscious, slow, and rational—and thus less prone to mistakes [2]. In unfamiliar situations, such as ordering a different muffin or navigating new roads, we employ the Deliberate System. However, once we practice a task enough, it shifts from the Deliberate System to the Instinctive System. For example, daily activities like brushing teeth and tying shoelaces may have initially been dependent on the Deliberate System, but over time, have shifted to the Instinctive System due to practice.

Furthermore, Tversky and Kahneman theorize that we tend to rely on the Instinctive System rather than the Deliberate System because we often resort to taking mental shortcuts rather than thinking our actions through [3]. However, this reliance on the Instinctive System often leads to mistakes. This happens because we base our decisions on past information rather than the information immediately available to us. For instance, before leaving your house, Apple Maps alerts you that your usual route to the local cafe is blocked. Despite this information, you still take the same path you have taken daily, just to reroute when you inevitably encounter the block. In this situation, you have based your decision on the fact that this route is the shortest and most accessible, prioritizing prior information over more recent and relevant information such as the road being blocked. It is our Instinctive System that causes this reliance on previous information. This dependence on the Instinctive System is further evidenced by the Wason selection task, a study first run by Peter C. Wason in which participants were presented with a logical, abstract puzzle containing four cards [4]. The puzzle was relatively easy to solve if the participant was paying attention—in other words, doing it consciously. At its simplest, this was a test of logic similar to the one described below.



The statement "If there is an A on one side of the card, then there is a 4 on the other side" is provided alongside four cards showing A, D, 4, and 7. The subject is told that each card has a letter on one side and a number on the other, and then asked to select only the cards that need to be turned over to determine whether the rule is true or false. While the correct answer was turning over the cards A and 7 (since it is the only combination that can falsify this rule) the two most common errors were failing to select the 7 or unnecessarily selecting 4. Wason found that despite the ease of the puzzle, participants repeatedly selected wrong answers that they were unable to explain later [4].

A potential explanation for these errors is that participants were relying on the Instinctive System to make decisions during the task, and were therefore unable to solve the puzzle correctly despite repeated attempts. The fact that the participants could not explain their answers suggests that they were not thinking logically or rationally. While the participants' shortcuts made the process quicker, it also led to biases and errors due to their reliance on past experiences and preconceived notions rather than a thorough analysis of information currently present. The puzzle required careful logical reasoning and conscious thought—it required use of the Deliberate System—but the participants relied predominantly on the Instinctive System, leading to poor decision-making [4].

Now that we have established that we *do* use two different systems when making decisions, it leads us to the question: what is the neuroscientific evidence for the dual processing model? Which neural regions are involved? Fink et al. established connections between the Instinctive System, the Deliberate System, and the frontal regions of the brain, which are active during conscious decision-making [5].

Fink et al. based their study on the assumption that creative activity uses the Deliberate System because it requires conscious effort, unlike mundane activity which is done routinely through the Instinctive System. In order to investigate this hypothesis, researchers created a test composed of four tasks—two were said to be creative while the two others were centered around verbal intelligence.

With the help of an electroencephalogram (EEG)—a non-invasive method of measuring the brain's electric fields—the study found that frontal regions of the brain were active while engaging in creative tasks [5]. The frontal regions of the brain are integral to voluntary movement, expressive language, and the management of higher-level executive functions, and therefore can be attributed to the Deliberate System. Furthermore, individuals with more creative answers had greater synchronization in the right than in the left hemisphere of their posterior parietal brain regions. These regions are related to spatial perception, maintaining an alert state by directing attention, and hand-eye coordination—all of which fall under the characteristics of the Deliberate System [5]. Hence, this study presents us with a stronger understanding of which brain regions play a role in conscious thinking utilizing the Deliberate System.

Now let's take a break and do a fun task to test whether you're conscious right now! State the color of the following words: **BLACK**, **GREEN**, **WHITE**. If your replies were black, green, and white, you were unconscious of what you were doing. However, if your answers were blue, red, and green, congratulations on making a conscious decision!

The test you completed was developed by John Ridley Stroop, whose findings led to the formulation of the Stroop Effect [6]. According to this theory, our ability to focus is limited to one source of information at a time. When faced with multiple sources of information at once, it is critical to make conscious decisions, as unconscious ones will lead to inaccuracies.

While Tversky and Kahneman's Dual Processing Model explores the Instinctive and Deliberate systems, the Stroop Effect delves into our inability to process multiple sources of information at a time, which Stroop classifies as selective attention. This leads to a delay in reaction time when we are presented with incongruent stimuli (conflicting sources of information presented at once), compared to congruent stimuli (no conflicting information) [6]. The Stroop Effect suggests that we are only able to focus on one aspect of complex problems and ignore other aspects. The delay in processing incongruent stimuli contributes to our understanding of how cognitive processes shape decision-making outcomes.

J. Ridley Stroop measured the time participants took to verbally report the color of the ink given in equal-sized lists [7]. The findings revealed that participants took approximately 47 seconds longer to identify the colors in the incongruent condition compared to the congruent condition [7]. During the congruent condition, the influence of the Instinctive System was predominant, characterized by automatic and unconscious processing. In contrast, the incongruent condition, which involved identifying the color of the words rather than the words themselves, required the Deliberate System, classified as a more cognitive and conscious effort. Participants encountered greater difficulty with the second task, often reading the word instead of its color, indicating the automatic response of the Instinctive System where participants answered unconsciously rather than consciously. Stroop concluded that the 74% increase in reaction time was due to interference, in which participants had to consciously use the Deliberate System to override the Instinctive System [7]. The automatic, unconscious nature of the Instinctive System creates tensions when individuals consciously attempt to engage the Deliberate System, resulting in interference and an observable increase in reaction time. This offers insights into the dynamics of cognitive processes during tasks that require selective attention and conscious decision-making.

However, in order to be fully convinced of the Stroop effect, we can look at the neuroscientific evidence. A recent experiment by Song and Hakoda helps to deepen our understanding of Stroop's observations on the cognitive mechanisms involved in processing incongruent stimuli by demonstrating how the Stroop Effect affects the neurobiology of certain parts of the brain [8]. Stroop Interference (SI) refers to the extended time taken to recite the color of the ink in the incongruent list, while Reverse Stroop Interference (RI) refers to the extent to which it takes longer to read a word written in an incongruent color. The researchers conducted four tests. Test 1, the control condition for the SI test, involved a color patch shown in the middle of the screen. The participants were asked to choose the matching color from five color words written in black ink. Test 2, the SI test, was the same procedure as the original Stroop study. Test 3 was the control test for the RI condition, where the color word combination was written in black ink and the participants were asked to choose which one matched the color patch (e.g. RED). Test 4 was the RI test, in which the color-word combination was written in incongruent ink (e.g. **RED**). The participants were once again asked to choose which one matched the color patch. Theoretically, if the correspondence between the semantic meaning of the word and the ink color did not affect semantic processing, participant results from Test 3 and Test 4 should not have differed [8].

After carrying out the test, the researchers concluded that RI interference must be closely related to activity in the prefrontal and cingulate cortices [8]. These regions relate to the activity of memory and reward. During Test 4, certain brain regions had to exert more cognitive control compared to Test 2, leading to the conclusion that the RI test is a better tool than the SI test. The left middle frontal gyrus (which plays a key role in the development of literacy), left inferior frontal gyrus (related to language, executive function and social cognition), and prefrontal lobe (which regulates our thoughts, actions and emotions) are all prefrontal regions commonly activated by the SI and the RI tasks [8]. Hence, the researchers were able to biologically prove the stimulus' effect during the Stroop test.

> "Tversky and Kahneman theorize that we tend to rely on the Instinctive System rather than the Deliberate System because we often resort to taking mental shortcuts rather than thinking our actions through [3]."

Now, after all that effort, what if I told you that according to some scientists, the Deliberate System does not exist? That you have no free will such that decisions are made in your brain before you think you've made them? You are probably puzzled and shocked, so let me explain. Let's suppose I ask you to flex your wrist at any point over a period of five minutes and then ask you to record the time at which you decided to flex your wrist. You may believe that you decided to flex your wrist at a particular time—let's say the two-minute mark. However, according to scientist Benjamin Libet, it was decided in your brain sometime before that mark.

Before we delve into the experiment, it is important to know that electric activity in neurons begins up to a second earlier than the actual movement when dealing with simple movements, and for an even longer time when dealing with a more complex series of movements [9]. This electric change is known as the readiness potential (RP). This RP is measured via EEG. Electrodes placed on the scalp record voltage potentials resulting from current flow in and around neurons [9].

Based on this RP, Libet's experiment contends that conscious decision-making is an illusion, and all decisions occur unconsciously well before the agent perceives them as conscious choices [10]. Libet supported this by measuring the time it took for a participant to consciously decide where they wanted to place their finger to mark the position of a moving dot around a circle while the researchers measured the voltage in the participant's relevant neurons. Libet found that there was a voltage spike in the neuron about 200 milliseconds before the participant lifted their finger, which was accompanied by unconscious activity about 550 milliseconds before the participant flexed their wrist via an EEG [10]. As a result, Libet claimed that unconscious decision-making precedes consciousness. This implies that none of our actions are conscious, and that free will is not possible.

In order to understand the neuroscientific implications, another modified version of Libet's experiment was conducted [11]. Eight participants were asked to perform a series of tests under EEG and electromyography (which records the electrical activity of muscles via electrodes) scanning, all involving the face of a clock with a revolving dot. In the first ("M") series, participants were asked to click a button at any point, and report at what moment, according to the position of the dot on the clock, they realized they had begun to click the button. The second ("W")

series was almost identical except that participants were asked to report when they felt the urge to first move. During the third ("S") series, the participants had a tactile skin simulator attached to their left wrist and reported the time at which they registered stimulation from the simulator. In the fourth ("P") series, also known as the pre-set series, the clock face presented the moving dot along with a bright green static "target" point. The participant's task was to click the button when the moving dot reached the target point. Similar to the W series, only the EEG was recorded. The results of all four series were found to be in accordance with Libet's theory that the brain decides the activity before an individual can sense that the activity will take place [11].

Hence, Libet's experiment gives us a lot to think about. Does our free will to do simple actions like flexing our wrists not exist? If it doesn't exist for these actions, does it also not exist for larger cognitive decisions that would classify as decisions under the Deliberate System?

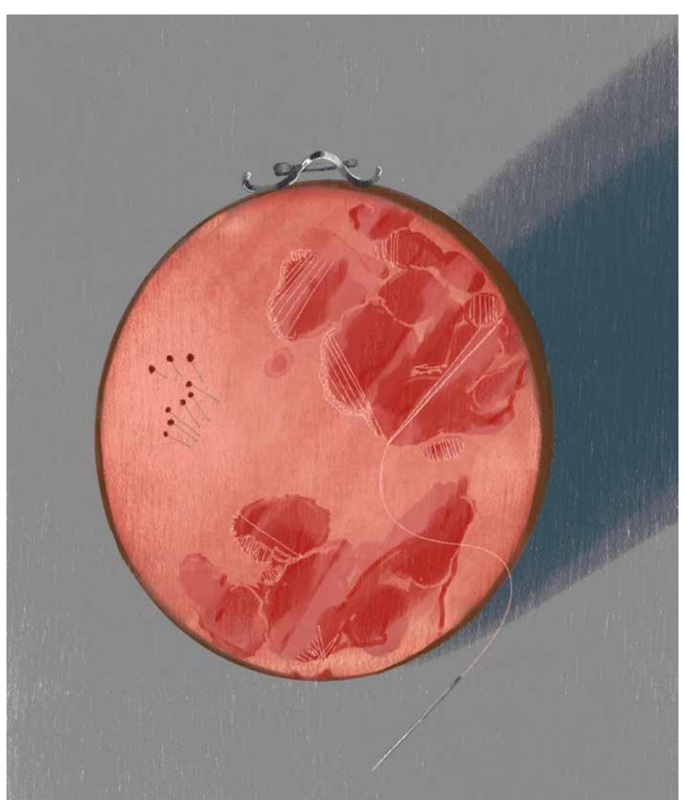
While Libet leaves us with a lot to ponder, I hope you remember that in all situations, you should not solely rely on your Instinctive System, but remember to switch to the Deliberate System when needed. Either way, the next time your favorite muffin is no longer available in the morning and you're forced to choose another one, remember that it is your Deliberate System at work. ♛

Your Brain on Pain

by Sloane Goldberg
art by Qingyang Meng

Everything in life revolves around sensations that cycle between pleasant and painful. A hot bath is soothing, but if you increase the temperature by 20 degrees? Painful. Walking is enjoyable, but stubbing your toe on the edge of the couch? Painful. Jalapeño salsa is tasty, but subbing in ghost peppers? Painful. In fact, pain is one of the strongest environmental learning cues we have. Young children learn not to touch hot stoves because they'll always remember the unexpected pain that shoots through their fingertips after brushing the burner. Even from a philosophical standpoint, we learn to avoid emotions like embarrassment or heartbreak because those feelings are uncomfortable and can even register as physically painful. However, these sensations are not consistent; a bee sting to one person is a nuisance, but to another, it can be insanely painful. What does it mean to have a high pain tolerance, or to push through the pain? How do our brains interpret painful sensations, and why is this interpretation consistently inconsistent?

Though pain is, well, painful, it has an evolutionarily important role in keeping us alive [1]. Individuals born with mutations in pain receptors that inhibit their ability to feel and understand pain often die before adulthood because sensing pain is an important part of staying alive. In these cases of what is called "congenital analgesia" (lack of pain from birth), placing your hand on a hot stove will still burn your skin, however, you wouldn't feel the searing pain that most people would expect. It might seem nice to avoid the painful parts of life, like banged elbows, paper cuts, or burns from a hot stove, but those signals are necessary to live. People with congenital analgesia often incur injuries most people wouldn't even consider, like biting your tongue off or breaking a bone without noticing. Some get hurt or even die doing dangerous activities like jumping off a roof or doing backflips on the lawn. Even though they may fall and crash into the ground, the event still doesn't register as painful, and therefore doesn't register as dangerous. Lack of pain doesn't prevent injury; it prevents learning that certain actions are harmful and must be avoided [1].



The way our brains and bodies deal with pain remains an area of active research. At the beginning of the 20th century, researchers identified specialized pain receptors called nociceptors, which are located in nerve endings that send signals through the skin [2]. These receptors respond to three kinds of triggers: mechanical stimuli like pressure or pinching (stubbing your toe on the couch, breaking your ankle), heat or cold (getting in a scalding bath or stepping barefoot into the snow), or chemical signals (eating ghost peppers or having an allergic reaction) [2].

Nociceptors only respond to sensations that reach a "noxious level" of stimulus [3]. For example, stepping out into brisk fall air will activate thermoreceptors, the receptors that respond to temperature, but falling into a frozen pond will activate nociceptors. At the most general level, these signals travel from the periphery into the central nervous system, transmitting signals from the skin or muscles to the spinal cord. This information is then relayed to the brain and interpreted in higher-level brain areas like the thalamus and the cortex. Because these signals reach important cortical areas so quickly, it is clear that these receptors exist to alert the brain to evolutionarily dangerous stimuli. Broken bones, allergic reactions, burns, and frostbite all pose potentially lethal dangers that must be conveyed quickly [3].

Yet not all these signals feel the same or even relay the same levels of risk. Eating spicy food might hurt, but it won't kill you. Additionally, the onset of pain doesn't necessarily relay its danger [3]. Stepping on a tack instantly causes a shooting pain that runs from your heel to your spinal cord, while generalized lower back pain may be less acutely painful but can still cause lifelong problems.

Pain is different from other sensations and environmental signals because the way it feels is easily changed by other stimuli. One initial theory of why pain can change in intensity is called the gate control theory, discovered in 1965 by two early neuroscience pain researchers, Wall and Melzack [4]. This theory states that both painful (nociceptive) and non-painful (non-nociceptive) sensory signals are transmitted to the spinal cord from their respective nerve fibers. If the painful signals outweigh the neutral signals, the nociceptive sensation is transmitted to the brain and the person feels pain. Conversely, the gate control theory states that if the "gate" or neutral sensations outweigh the painful ones, the amount of pain a person experiences is diminished [4]. This theory aims to explain why rubbing or massaging a spot in pain can sometimes help eliminate the pain. For example, holding your side (the "gate" in this case) can eliminate a cramp (the pain), or rubbing a sore muscle can alleviate discomfort [5, 6].

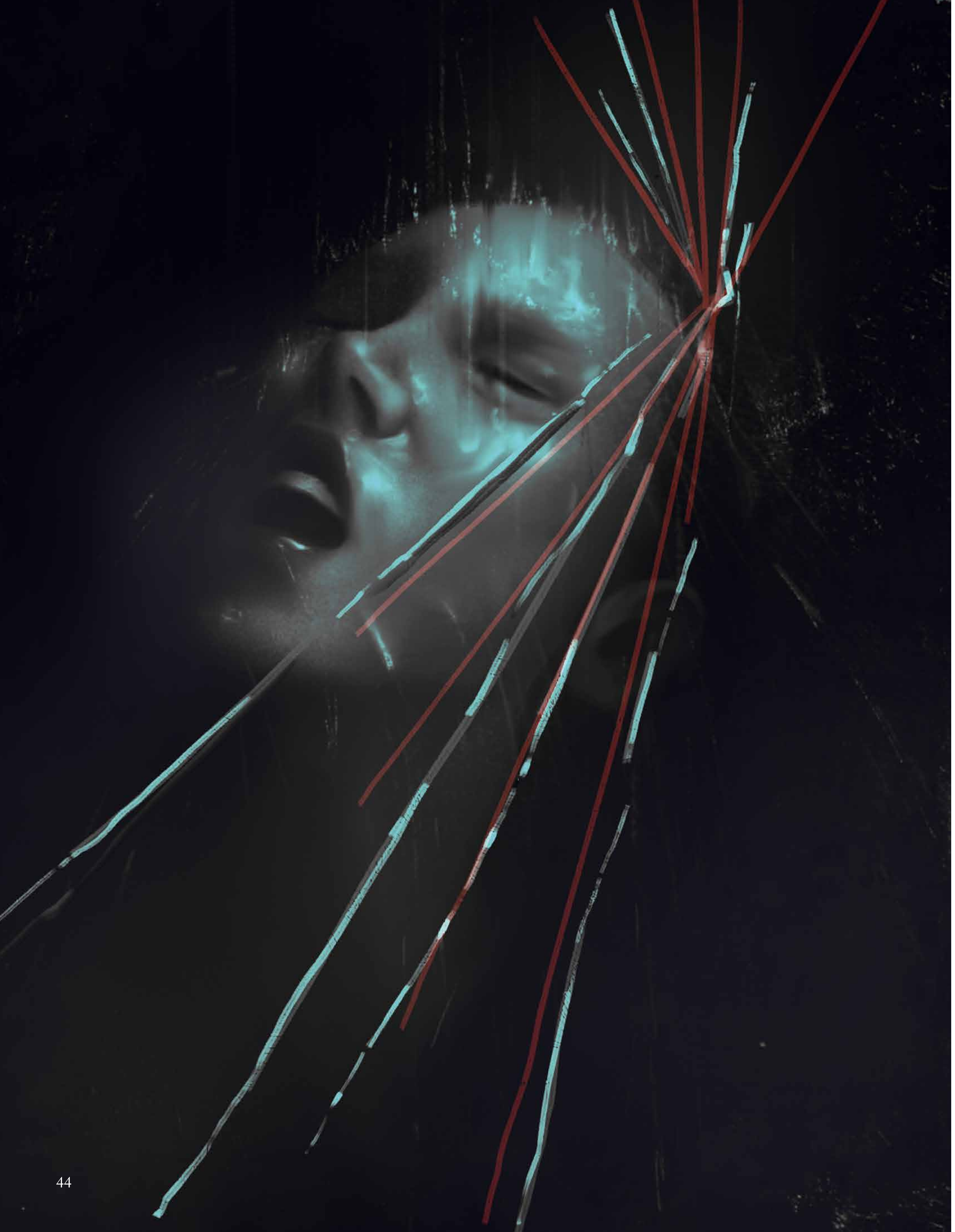
"Endogenous opioids don't cause the same off-target effects as synthetic opioids like morphine because they are delivered directly to the targeted sites by immune cells, while synthetic opioids act anywhere opioid receptors can be found."

Still, significant questions remain as to why people experience the same pain differently. The gate control theory doesn't explain why two people might experience the same stimulus (for example, a broken ankle), yet have completely different perceptions of pain [5]. Additionally, the gate control tactic has limitations and doesn't seem to ever block out pain entirely, only alleviate some of the intensity [5].

Part of the answer to why people feel pain in different ways lies in arguably one of the most discussed drug targets in the brain: opioid receptors [5]. Known primarily for their media focus in the past two decades, opioids are a class of drugs prescribed for intense pain relief, like morphine or fentanyl. The drugs also cause feelings of relaxation and euphoria, inciting a high potential for abuse. Opioid receptors are the proteins these drugs bind to, which set off a chain of events in the spinal cord and brain to decrease pain. Though the exogenous (external) drugs attract more public attention, opioid receptors, and some forms of opioids themselves, are endogenous, meaning they are naturally produced by the body in response to stimuli like a broken arm or twisted ankle. Endogenous opioids don't cause the same off-target effects as synthetic opioids like morphine because they are delivered directly to the targeted sites by immune cells, while synthetic opioids act anywhere opioid receptors can be found. This explains why morphine might make you feel euphoric, but a broken ankle doesn't suddenly cause delirious relaxation [5]. There are three main kinds of endogenous opioid receptors: the mu (μ) opioid receptor, the delta (δ) opioid receptor, and the kappa (κ) opioid receptor, which all bind different types of opioid peptides in the spinal cord and cortex [7].

Though exogenous opioids have made headlines in the past two decades as drugs of potential pharmaceutical abuse, endogenous opioid receptors are involved in many different processes, such as emotional regulation, immune function, respiratory and cardiovascular systems, and even trigger hibernation in some mammals [8]. In the context of pain relief, synthetic opioids like morphine, fentanyl, and oxycodone work because they enhance the same systems that are already present in the body [8]. For example, one study showed that levels of β-endorphin, an opioid peptide that binds to the mu receptor, increased in the blood following muscle injury or dangerous infection, indicating that an injury causes these endogenous opioids to be released [9]. The study stated that binding between the naturally occurring β-endorphin and the mu receptor (which also binds fentanyl and morphine, and is blocked by naloxone) induced analgesia, or pain relief [9].

Similar studies have also indicated that endogenous opioid receptors are needed for natural pain regulation. Mice without mu opioid receptors are overly sensitive to heat, while those without delta opioid receptors experience more intense mechanical pain like pressure or pinching [7]. Additionally, mice without kappa opioid receptors exhibit stronger reactions to triggers of visceral, or internal pain [7]. In another study, dental patients who were given naloxone, which blocks endogenous mu opioid receptor binding, showed similar results [5]. These



patients, whose mu opioid receptors could not bind endorphins, experienced significantly more pain than those given a placebo. Essentially, blocking the binding of natural opioids to their receptors increased pain because it prevented the body from responding to the pain [5].

Despite this understanding that endogenous opioids do exist and block pain, the opioid system is exceptionally tricky to understand. For one, opioid application doesn't always relieve pain [10]. One study revealed that while low levels of exogenous morphine application resulted in decreased pain responses in mice, high doses of morphine increased pain responses, indicative through behaviors such as scratching, biting, and licking. Furthermore, these symptoms were not reversed by naloxone, which blocks opioids from binding to their receptors and often used to reverse opioid overdose. In humans, high levels of exogenous opioids, such as in someone abusing drugs like oxycontin, have been linked to a heightened level of pain, sudden muscle contractions, and pain in response to non-painful stimuli like light touch. With opioids, there is such a thing as "too much of a good thing." Opioid overuse causes far more problems than it solves [10].

Still, it is not well understood why small doses of opioids are extremely helpful in reducing pain, while high doses cause the exact opposite effect [11]. The current theory posits that morphine not only binds to mu opioid receptors that inhibit pain, but it also binds to other excitatory receptors like glutamatergic and NMDA receptors. Excitatory receptors "excite" other parts of the body and brain instead of inhibiting, leading in some cases to more pain. These receptors are partially responsible for the "off-target effects." When our bodies naturally produce opioids, we produce precisely the right amount to bind only to opioid receptors; when we add opioids exogenously, there is less control over where they go. Thus, at higher concentrations, morphine is more likely to set off a chain of events that carry painful signals to the brain, rather than preventing pain [11].

So how does pain modulation look in practice? One of the best ways to examine how endogenous opioids can change the way we feel pain is through the lens of one of the most common health issues in America: back pain. According to one study, as many as 70-85% of people report back pain at some point in their lifetime, and a sizable percentage report chronic pain, called Chronic Non-Specific Back Pain (CNBP) [3]. A separate study found that when people who reported CNBP received a painful stimulus, their brains showed lower levels of mu opioid receptor activation in the thalamus. This means that some people with chronic pain demonstrate difficulty activating these inhibitory systems, which are supposed to prevent painful signals from reaching the brain. Instead, such individuals experience amplified pain signals, and often develop a secondary chronic condition. It is not clear if this inability to activate mu opioid receptors is a factor of chronic pain, the cause of chronic pain, or some circular combination of both. Regardless, the study provides some insight into why people with CNBP feel pain more intensely than those without it [3].

> "...pain catastrophizing, or stressing about anticipated pain, can also impact how strongly one experiences pain."

One thing, however, is clear: treating back pain with exogenous opioids, the way doctors did throughout the 2010s, tends to be more dangerous than beneficial [3]. If patients cannot bind opioids to their mu opioid receptors in the spinal cord, adding more chemicals that attempt to bind to the same receptor does not solve the problem. Rather, it creates new problems, including the potential for addiction. Therefore, one chemical theory for why people feel pain in different ways has to do with their ability to activate opioid receptors via endogenous opioids in the nervous system. If someone cannot bind endogenous opioids, which are released in response to trauma, then they are likely to experience more intense pain and decreased pain tolerance [3].

The overlap between chronic pain and overall pain tolerance also provides an interesting model to study the way chemical signals and mental signals connect. One study, also focusing on chronic pain, found that individuals with anxiety disorders, including post-traumatic stress disorder (PTSD), generalized anxiety disorder (GAD), panic disorder (PD), and/or social anxiety disorder (SAD), showed a strong co-occurrence of chronic pain [12]. One potential explanation is that rather than anxiety causing chronic pain or vice versa, both disorders help maintain each other in what is called a "mutual maintenance model." For example, in the instance of PTSD, distress and anxiety can remind a person of physical pain, which provokes a physical response to the trauma. Another theory asserts that anxiety disorders create a "lower threshold for alarm," meaning that someone with an anxiety disorder is more likely to experience a strong stress response with a lower-level trigger. The bodily changes caused by arousal, such as high blood pressure, fast heart rate, quick breathing, and tense muscles, can be destructive when prolonged, in the same way that chronic pain provides consistent activation of systems that are only meant for short-term activation. When in a state of stress, the body responds by decreasing the rates of digestion, immune responses, and muscle regeneration. This overlap describes one component of what we might call pain tolerance, in which the base level of how anxiety activates a stress response plays a big role in how a person might tolerate physical pain [12].

In a similar vein, pain catastrophizing, or stressing about anticipated pain, can also impact how strongly one experiences pain. One study suggested that the main predictor of reported pain was how painful the subject expected the experience to be [13]. This expectation then creates a self-fulfilling prophecy. Take, for example, getting a flu shot at the doctor. If you expect the shot to be extremely painful, your body will respond accordingly; your muscles will tense, you might wince in expectation, or you experience an increased heart rate. Since you anticipate the shot will be painful, you're more likely to experience increased pain, which in turn will validate your expectation of pain. This feedback loop will solidify the belief that shots are very painful, and the next time you get a shot, you'll be reminded of how painful it was the time before, and so on. A different person may have the same biological response of beta-endorphins and opioid receptors, but lower expectations of pain, which will cause them to experience less physical pain during and after the shot. Expectations exacerbate pain intensity, which in turn changes pain tolerance [13].

This theory of pain catastrophizing was replicated in another study. Here, the researchers told subjects to place their hands in cold water [14]. Before the task, half of the subjects were told that the task might be dangerous and lead to nerve damage, while the other half was informed that the task would not result in any kind of injury. The first group exhibited significantly higher anxiety before the task, and that increased anxiety

caused more intense feelings of pain. In contrast, the second group did not report increased anxiety and found the task to be less painful [14].

So why does your hand hurt more than your friend's when you both trip and fall on the pavement? The answer is complicated. Your level of chronic pain and endogenous opioids play a role, and your anxiety and mental state might impact the feeling. Or, perhaps as you were falling towards the concrete, all you could think was "this is going to hurt so much." Neuroscience research has only scratched the surface of how we feel pain and why it is so unreliable. All we know is that the systems that convey pain from our fingertips to our brains are modulated in many different places along the way, changing the overall sensation and the way we interpret it. Pain is unpleasant, and humans spend so much time, money, and effort avoiding it. Ironically, however, pain is necessary to live. It's a warning sign, sending rapid signals to your brain that say "hey, this thing might kill you, let's not try it again." It's an inconsistent signal, and an imperfect one, but it exists for a reason: pain keeps us alive. ♛

Perfectionism Paradox

by Emma Kornberg
art by Jillian Smith

We have all heard of, been around, or known people who are perfectionists. Maybe we look at them and think: how do they do it? How do they accomplish so much with seemingly endless energy and motivation all the time? It may come as a surprise then, that research suggests drawbacks to these perfectionistic tendencies, including a higher risk for mental health issues. Because society highly values productivity and high achievement, emphasized on mediums like social media, the cyclical validation of perfectionism is, unfortunately, perpetuated.

Certain people are extreme perfectionists, but most only exhibit some perfectionistic tendencies. Wherever a person falls on this spectrum, it is helpful to practice more adaptive strategies that embrace the positive aspects of perfectionism, such as internal motivation and goal setting, while avoiding more negative qualities such as extreme self-criticism.

Adaptive and Maladaptive Perfectionism

Perfectionism is characterized by aiming for an unrealistically flawless level of performance even if it is beyond what the situation actually requires [1]. The trait is divided into two categories: adaptive and maladaptive [2]. The two types differ based on motivations to succeed, how mistakes are viewed, and goal-achieving processes.

"Wherever a person falls on this spectrum, it is helpful to practice more adaptive strategies that embrace the positive aspects of perfectionism, such as internal motivation and goal setting..."

Adaptive perfectionists tend to be self-oriented, or internally motivated by a desire to succeed [3]. Because of this, they have a higher sense of personal control over their actions, allowing them to selectively put effort into tasks they choose to prioritize, rather than overworking themselves. This internal feeling of control also applies to their handling of failure, as adaptive perfectionists allow more room for error, allowing instances of failure to guide future directions [3]. Consequently, these individuals build more adaptive and intuitive strategies, such as reframing a negative situation to look at the positives [3, 4]. This also means that adaptive perfectionists enjoy higher self-confidence since they are able to acknowledge their past successes in the face of failure, rather than focusing solely on their shortcomings [3]. Because of this heightened confidence, adaptive perfectionists are able to recognize their own limitations without seeing them as failures, leading them to set more attainable goals for themselves [5].

Maladaptive perfectionists, on the other hand, are usually motivated by external factors, such as societal or parental pressure, and are mainly driven by a fear of failure, which can be far more harmful to mental health [6]. This type of socially-prescribed perfectionism can feel incredibly isolating. Fearing that the outside world will harshly scrutinize their flaws, individuals can become consumed with negative self-talk and plagued by an inability to move past mistakes. This societal pressure may also cause individuals to exhibit other-oriented perfectionism [6]. Because maladaptive perfectionists perceive the world as intensely judgemental, they also place heavy expectations on others, contributing to an overall sense of societal disconnect and isolation [7]. To illustrate this difference, we can consider both maladaptive and adaptive responses to receiving a poor grade. An adaptive perfectionist might still feel proud of their efforts and be able to move forward. They will likely be able to reflect on what went well and what could have gone better without much self-criticism. However, a maladaptive perfectionist will likely take this grade as an indication that they are personally a failure and will be judged by the rest of the world. They hide this grade from others and heavily self-criticize, spending a lot of time thinking about this unacceptable and shameful imperfection [8].

There is an overlap between maladaptive and adaptive perfectionism, as different situations can give rise to different kinds of responses. Adaptive perfectionists can react with more harmful responses if under pressure or incorrectly thinking that an unhealthy coping strategy would be helpful [9]. Thus, both maladaptive and adaptive perfectionists can face consequences, although adaptive individuals may have a clearer pattern of healthy coping. Further, both types face the risk of taking repeated failures very personally, thinking that they are the core problem [9]. Being aware of which strategies are generally healthier and more useful for an individual with perfectionistic tendencies is important to help avoid intense self-criticism, low self-esteem, and poorer mental health [10].

> *"Failure is a difficult experience for most people, and for perfectionistic individuals who are predisposed to feeling some degree of imposter syndrome, external as well as internal judgment or shame can be amplified."*

Perfectionism is related to brain regions involved in cognitive and emotional processes, specifically the anterior cingulate cortex (ACC) [11]. This area has connections to the limbic system, brain regions associated with emotional regulation, and the prefrontal cortex, which is linked to cognitive processes. The ACC is crucial in the ability to regulate negative emotions, which we do without realizing all the time [11]. For example, when receiving bad news right before an exam, we are generally able to use strategies such as suppression, emotionally distancing ourselves from the news, or distraction, so that we can focus on the exam. Afterward, we can turn our attention toward our feelings about the news and process them.

The ACC is activated by reward and emotional stimulation, so activities such as cognitive control, error detection, fear-related judgment, and emotional conflict regulation would likely excite this region [11]. Perfectionists tend to experience some fear of failure and external judgment, which can incite complicated and possibly negative emotions [11]. Thus, we can see how this brain area might be implicated in perfectionistic strategies. In fact, some sub-dimensions of perfectionism (concern over mistakes and doubts about actions), which are associated with anxiety and depression, are positively correlated with grey matter volume in the ACC [12]. Grey matter is the outermost layer of the brain and is crucial for daily operation, so changes in its volume can have a profound effect on the level of functioning [13].

Self Efficacy and Imposter Phenomenon (IP)

Adaptive perfectionists express higher levels of self-efficacy, or a person's belief in their capability to complete tasks successfully, than maladaptive perfectionists [3]. It is crucial in achieving goals because people with a higher sense of self-efficacy are more likely to be patient when facing obstacles, believing they have the skills to overcome them [14].

High self-efficacy is associated with a positive effect on academic performance [15]. For example, a student with high self-efficacy confidently relies on problem-solving skills and tends to put more effort towards understanding the material in front of them. They believe they have the necessary tools to put in hard work, knowing that they will eventually learn the information. Additionally, because they do not view failure as a reflection of personal ability, they feel motivated to move forward. One idea as to why this is the case is that students who experience positive emotions as they learn (as opposed to anxious and self-critical ones) are able to engage more deeply with the material and act more flexibly [14]. We tend to feel more comfortable asking questions to fill in the gaps and understand the topic deeply when we resonate with it. Instead of being distracted by feelings of panic and anxiety about being inadequate, we can view learning as positive and meaningful.

Going into a learning experience with low self-efficacy creates more negative feelings surrounding the experience, causing one to avoid engaging deeply with the material [14]. Lower self-efficacy manifests in avoidance and procrastination, which can in turn lead to worse performance. Individuals may fear that a task is too difficult, causing them to give up easily. When faced with failure, they take it more personally, believing that it highlights a lack of personal ability instead of effort [14].

Low self-efficacy is also associated with the imposter phenomenon (IP), which was first described in 1978 as an internal feeling of inadequacy and low self-confidence about one's abilities despite evidence suggesting otherwise [16]. The concept has since evolved to include feelings that one is undeserving of their successes, falsely believing that these successes are the product of good luck as opposed to conscious hard work and effort [17]. The final aspect of this phenomenon is the fear of being exposed as an "imposter," which can lead to anxiety about having tricked others into overestimating their abilities [17].

IP is especially prevalent in rigorous academic and professional contexts, such as medical school. Franchi and Russell-Sewell at the University of Sheffield found that up to 65% of medical students in their study had experienced scenarios in which they felt they were an "imposter," despite being highly accomplished [18]. They found that this was more prevalent in women and that social comparison, which can be higher in people with IP, likely played a contributing role [18].

Another example is found in minority first-generation college students, who tend to experience IP more often than non-first-generation students [19]. This could be due to a lack of substantial institutional resources for minority students, intense family pressure, or limited family support. Because these students are the first in their families to pursue higher education, they may sustain more self-doubt and feelings of inadequacy as they undertake a completely new challenge differently than non-first-gen students [20].

Social Media as a Medium of Socially-Prescribed Perfectionism

On average, young people spend 4.8 hours a day on social media. On these platforms, comparison to others is unavoidable and can contribute to the sense of isolation associated with socially-prescribed perfectionism [21]. Research has shown that more time spent on social media is correlated with higher levels of loneliness, even when adjusted for age, employment, concerns over health issues, and living with a partner [22].

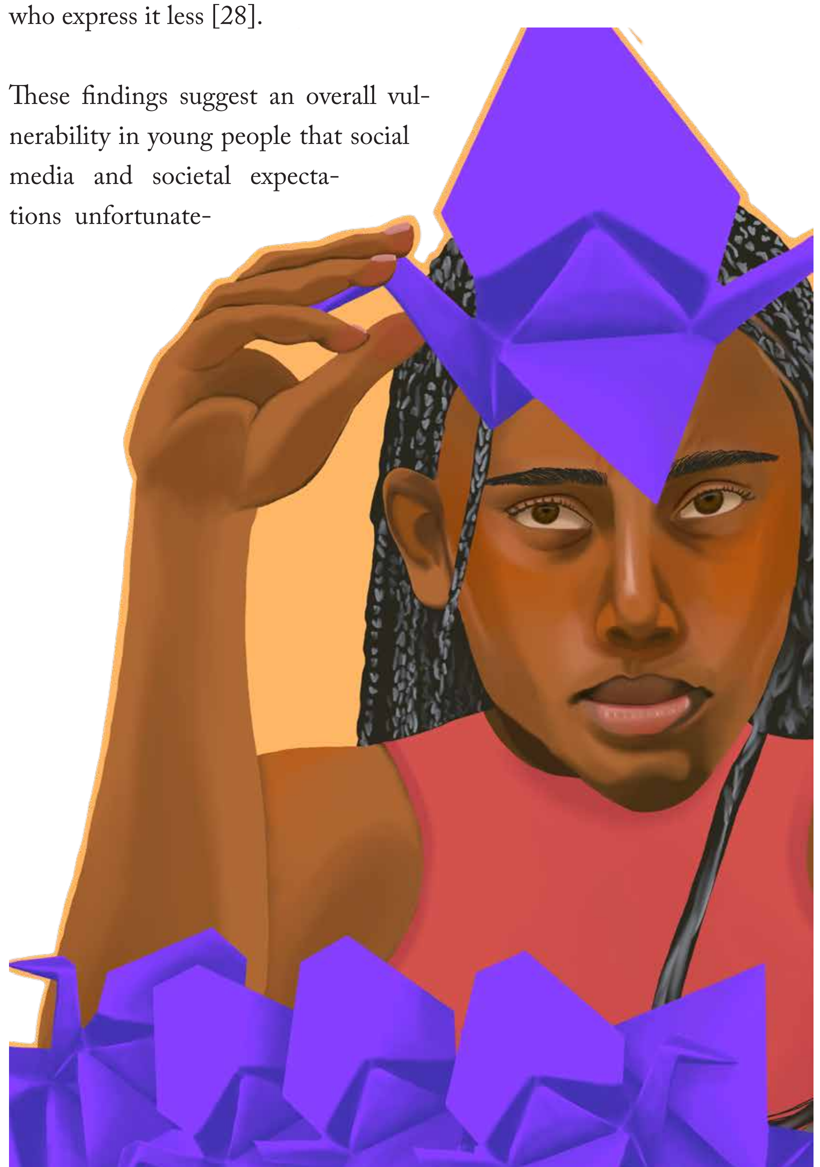
On social media, users see "perfectly" productive days, "perfectly"-shaped bodies, and "perfect" relationships. This leaves viewers to examine their own lives, which seem flawed in comparison, and wonder how to "fix" everything to make their lives more perfect. We know that this probably won't make us happy, but we admire the people on social media, and maybe we want to appear flawless to others too!

For many perfectionists, this experience can feel more intense, as they may set particularly unrealistic and unattainable expectations based on social media. Overusing social media has been linked to high academic burnout and other harmful aspects of perfectionism, such as self-criticism or intense rumination over mistakes [23]. It can also increase the sense of socially-prescribed perfectionism, exposing people to "flaws" they didn't even know existed and increasing self-consciousness of these presumed flaws [24].

Some studies have shown that social media comparison can lead to increased dissatisfaction with appearance and weight, as well as decreased confidence. Specifically, common features of maladaptive perfectionism, such as rumination (an intense focus on critical thoughts) and catastrophizing (fixating on an anticipated negative event, magnifying the outcome, and underestimating coping ability), can amplify the effects of this comparison [25, 26]. These coping mechanisms have been found to decrease self-esteem levels, explaining the increased negative effect of social media comparison [27]. On the other hand, adaptive coping strategies such as positive refocusing can actually lessen the impact of perfectionism on one's confidence [28]. Positive refocusing is used to reframe stress-inducing events as somehow beneficial or having a bright side [29, 30]. For example, a person nervous about failing their driving test may tell themself: "Even if I fail, that does not mean that I am a failure. This event can highlight some of my weaknesses, which I can improve over time. Thus, this is a valuable experience where I get to learn the extent of my abilities."

Because comparison on social media can enhance perfectionist qualities, especially relating to physical appearance, it is important to be mindful of the risks that this environment poses, especially for younger adults and teens. Studies have found that younger adults express higher levels of perfectionistic traits than older adults [9]. In children and adolescents, perfectionism is directly correlated with eating disorder symptoms [31]. This may be because those who tend to express greater perfectionism in the area of self-appearance experience more self-dissatisfaction and lower confidence than those who express it less [28].

These findings suggest an overall vulnerability in young people that social media and societal expectations unfortunately perpetuate. Interestingly, in one study, participants concluded that despite reporting increased self-dissatisfaction and lower self-confidence, they did not feel that they were negatively affected by comparing themselves to individuals on social media [28]. This highlights a lack of awareness about the impacts of social media comparison on mental health, and perhaps an integration of socially-prescribed perfectionism into what may convincingly appear as self-oriented. Thus, it is important to be conscious of the comparisons that social media compels us to make and how they affect us.



Maladaptive Perfectionism and Drug Abuse

Because perfectionism inherently poses a constant source of stress and pressure, it can result in low self-esteem and frustration about always falling short of high expectations. An inability to cope with stressful situations or simply a lack of the proper coping tools, both features of maladaptive perfectionism, is a risk factor in the onset of drug abuse [5]. This is especially important to be aware of due to possible comorbidities, or the possibility of multiple disorders being present in an individual. For example, 50% of individuals with eating disorders, which implicates perfectionistic traits, also use alcohol or illegal drugs [32]. In fact, one in five individuals with an eating disorder will develop a substance abuse disorder sometime during their life [33]. Interestingly, studies suggest that aspects of adaptive perfectionism can help to prevent substance abuse, while traits of maladaptive perfectionism can increase the risk of an earlier onset of substance abuse [5, 10]. Specifically, the self-blame and low self-esteem found in maladaptive perfectionism can cause heightened feelings of frustration and dissatisfaction, which can result in leaning toward substance abuse as a possible coping mechanism [10].

Maladaptive coping strategies include prioritizing negative emotion over problem-solving, possibly leading to social withdrawal or living in denial [5]. These perfectionists feel ashamed of their mistakes and judged by the rest of society, leading to unhealthy behaviors that perpetuate a cycle of anxious and depressive symptoms. Because avoidance can feel less painful than the negative feelings associated with falling short, maladaptive perfectionists may be at a higher risk of turning to substances than others [5]. In fact, severe alcohol use disorder is associated with greater self-oriented and socially-prescribed perfectionism as compared to healthy control participants [7]. Thus, it is crucial to practice healthier coping strategies that are more commonly associated with adaptive perfectionists, such as adopting

a problem-solving mindset, practicing cognitive flexibility to view the environment as less threatening, and viewing failure as a learning experience instead of a personal shortcoming [5].

Perfectionists may fear mistakes and flaws, even though these are recognized as typical aspects of life—after all, to err is human. Failure is a difficult experience for most people, and for perfectionistic individuals who are predisposed to feeling some degree of imposter syndrome, external as well as internal judgment or shame can be amplified. This can lead to isolation and pressure, which contribute to long-term mental health issues such as anxiety, depression, or burnout, among others [12]. While there is no perfect way to be a perfectionist, practicing healthier strategies and increasing awareness regarding the downsides of portraying perfectionism as a purely positive trait may be beneficial. ♔

System Overload: A Byte-Sized Problem

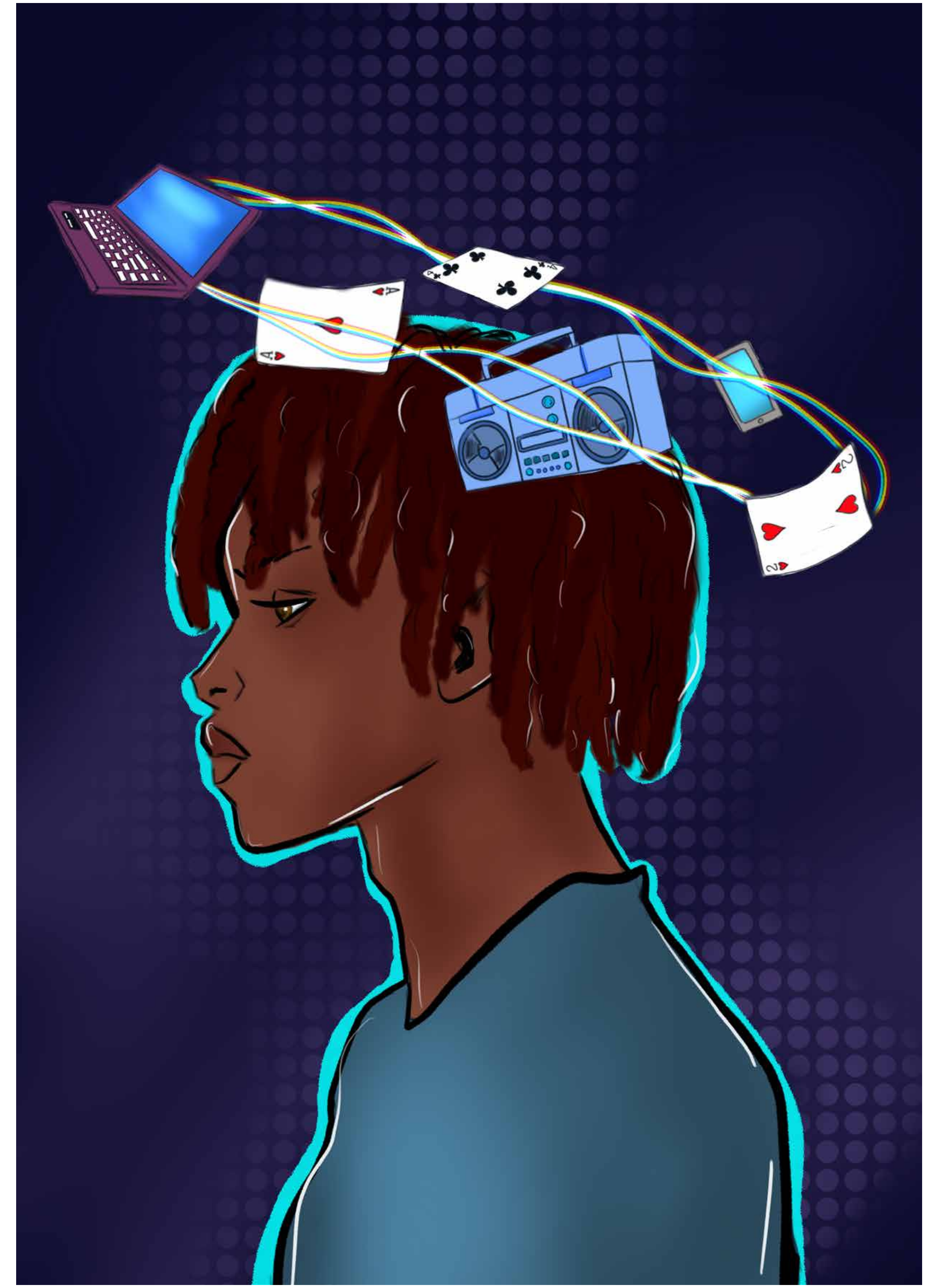
by Anahita Aggarwal
art by Hailey Kopp

Early one morning, after a night spent researching the material that you will encounter in this article, I reached my first class of the day. As is always the case for days on which you skip the readings, my professor called on me — he wanted to hear my thoughts on "homosociality." There were no such thoughts, however, the name of the paper's author (Eve Sedgwick) seemed familiar. Somehow my memory system had held onto a video of a Tiktok-certified love counselor sharing her theory that men are more obsessed with male validation than women, and more importantly, the comment that read, "What Sedgwick thought she did." TikTok had made its way into my unconscious brain (and saved the day!). Unfortunately, there are significantly more instances when the internet's lingering influence on the brain can result in a less pleasant experience. If I looked around the same class, many laptop screens would probably reveal the New York Times crossword puzzle, an online shopping website, or maybe just the readings (for a different course). Even if someone's laptop screen were blank, any of the above could still be on their mind.

A 2015 study investigated the persisting effects of technology on an individual's mental state, in cases where technology was not actively in use [1]. Researchers found that simply receiving but not viewing or responding to a text message can significantly compromise performance on attention-demanding tasks. This remained true even when subjects did not intend to read or respond to the text [1]. Other studies have demonstrated that merely keeping your phone by your side, regardless of whether you receive a notification, can critically impact your performance on attention-intensive tasks, for example, a quiz on lecture material [2]. It is important to note that though the two studies above evaluated participants on attention-related tests, the underlying issue is not purely attentional. Researchers from the aforementioned study associated impaired task performance with "nomophobia," the anxiety experienced when you are unable to access your cell phone [2]. Since cell phones are inextricably linked to our social lives, nomophobia encompasses different domains of anxiety such as losing connectedness and being unable to access information. Therefore, while attention-based tests are an objective way of assessing the impact of technology on an individual's mental state, one of the reasons behind an impaired performance is thought to be a more general feeling of "fear and discomfort" [2].

On a more personal level, I have seen such fears being grouped under the umbrella term of being "overwhelmed," a word that comes up often in conversations with friends. Feeling overwhelmed is multifaceted, but in the context of technology, a possible biological explanation could be through the concept of "stimulus overload." A stimulus is an external or internal input that provokes a response from our biological systems, such as sound being detected by mechanisms in our ears and transduced into neural stimuli, or light being processed by our eyes and sent to the brain [3]. However, this stimulation can occasionally be too excessive to handle, resulting in stimulus overload and causing our capacity for receiving and processing information to become severely taxed. Some overload may be attributed to

> "Researchers found that simply receiving but not viewing or responding to a text message can significantly compromise performance on attention-demanding tasks."



sensory stimulation such as excessive noise, crowding, or environmental complexity arising from paying attention to too many people at once [3]. For instance, a crowded physical space could result in overload due to difficulties that arise when processing too many stimuli; the internet provides us with access to millions of people at once, significantly more than could fit in a physical environment. How does this immense leap impact our processing abilities?

One way to understand how accessing the internet can lead to overstimulation is by considering the internet as a "supernormal stimulus." This term originates from evolutionary theory and is used to denote an artificially produced stimulus that elicits a greater response from our reward systems than its naturally occurring counterpart [4]. The idea is that such stimuli activate systems in the brain that evolved over thousands of years in natural environments, but do so in an exaggerated manner due to their enhancement. For example, fast food stimulates our taste buds to a much greater extent than its individual ingredients found in nature [4]. In the case of social media, supernormal stimulus effects could be produced by allowing you to engage with many more people than would have been physically possible. A 2013 paper provided specific examples where social media could have the above effect [5]. Among the most interesting findings is that relatively unidirectional forms of internet-based communication, like tweets that do not necessitate a response, could stimulate the reward systems responsive to social sharing while protecting the individual from costs due to social anxiety. Another example is the ability to utilize social media to experiment with alternate identities fulfilling psychological needs such as the desire to be understood without incurring interpersonal costs [5]. In both of the above situations, social media helps an individual satisfy certain needs that chemically reward the brain without facing the costs — such as the anxiety stemming from social situations — that are often associated with the fulfillment of that need in the natural world. Thus, the internet can be considered a supernormal stimulus that interacts with brain regions that insufficiently adapt and process the stimuli associated with new technologies, leading to overload.

The two main systems in the brain that tend to overload in response to internet-associated stimuli are the dopaminergic and working memory pathways. Dopamine is a neurotransmitter that is associated with pleasure, motivation, and learned behavior [6]. It is released when we engage in activities that please us, such as taking a bite of our favorite food or listening to a great song [6]. Since dopamine release has a "feel-good" effect on the brain, it motivates us to repeat the behavior that stimulated its release. This loop in turn facilitates learning. There are two specific mechanisms that I would like to discuss with respect to learning, the first being "reward prediction error." This refers to the difference between the reward that's anticipated by an individual and the reward that is actually received [7]. Dopamine is secreted in anticipation of a reward, but this chemical response will change depending on how pleasant your experience of the reward is. If the reward is beyond expectations, the reward prediction error is positive and dopamine levels spike, but if the reward falls short, the error is negative and dopamine levels reduce from the average level [7].

With social media, since likes and comments stimulate the same part of the brain that secretes dopamine after successful social interactions, seeing an unexpected complimentary comment could trigger a positive prediction error and trigger an increased release of dopamine [8]. On the other hand, receiving no comment at all could be a negative prediction error, and result in an individual compulsively scrolling and waiting for a reward. The second process is related to "long-term potentiation," which implies that every time a stimulus results in a reward, the connection between them in the brain is strengthened [9]. So, each time that scrolling on social media results in finding a complimentary comment, the desire to scroll again is made even more powerful. Social media — providing an endless opportunity for such prediction errors in the form of likes, comments, text messages, and more — acts as a supernormal stimulus and overstimulates the dopamine pathway.

A 2012 study compared levels of dopamine transporters (DAT), which regulate dopamine levels between communicating neurons, in two groups: one with clinically diagnosed Internet Addiction Disorder and the other a control group who did not overuse the internet [10]. Researchers found that DAT levels were significantly reduced in individuals with internet addiction. The study showed that individuals with internet addiction may experience a greater concentration of dopamine release while playing video games or interacting with the internet, but researchers suspected that the high levels of dopamine caused damage to the dopaminergic system and resulted in lower levels of DAT. The reduced DAT levels cause an individual to seek out dopamine more often, resulting in a cycle where they will repeat the behavior that caused the condition in the first place [10].

Another important brain system that is compromised by internet-related overstimulation is that of working memory. Working memory refers to the capacity to hold information temporarily to use it for cognitive purposes [11]. When we solve mathematical equations, the various numbers required for calculation are stored in our working memory. Individuals with pathological gambling have been shown to have reduced working memory capacities than the general population, and a 2016 study compared their working memory function with those who are addicted to the internet [12]. The premise is that scrolling on the internet requires you to hold a significant amount of information in your working memory at one time, like in the case of gambling, and it can overwhelm your working memory system. Researchers found that individuals with pathological gambling and internet addiction performed similarly on a working memory task, and both groups had significantly lower test scores than the control group of the general population. Working memory capacity is critical for executive function, an umbrella term for cognitive processes such as reasoning, decision-making, and problem-solving. The same study demonstrated that individuals with pathological gambling and internet addiction experienced the same degree of dysfunction in their executive control abilities [12]. This manifests in impulsivity and novelty-seeking behavior, both traits that further encourage internet use — for instance, seeking novel stimuli on TikTok or impulsively picking up your device when you have other tasks planned.

So, what can someone do if they feel overwhelmed by their internet use? The most frequently suggested treatment for sensory overload is "restricted environmental stimulation," or a reduction of sensory and informational load [3]. The problem

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in the case of overstimulation induced by excessive device use is that preventative measures require an increase in self-regulation, while overuse of the internet results in a severe disruption of self-regulatory mechanisms [13]. In other words, the people who would benefit the most from reduced stimulation by the internet would also face more difficulty when trying to enact that change. An important example is "internet gaming disorder," which, as indicated by the name, is caused by immoderately playing video games [14]. This disorder is actually included in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), with "withdrawal symptoms, lack of control, and mood modification" included in the diagnostic criteria [14]. Executive function, mentioned above, helps us inhibit certain desires and limit engagement in unfavorable behavior. A 2015 study found individuals with internet gaming disorder to have impaired executive function [13]. This study perfectly captures the complication of overstimulation by the internet, since reducing the time spent playing video games would help treat internet gaming disorder but impairment in executive function makes that reduction much more difficult.

A possible technique to avoid the effects of supernormal stimuli associated with the internet could be to stimulate the release of rewarding neurotransmitters in a more natural way – offline. The idea would be to reduce an individual's dependence on the internet while simultaneously finding a less overstimulating replacement for the effects that it produces. A study conducted on other mammals revealed healthier ways to stimulate the release of "feel-good" chemicals in the brain without applying additional stress to their signaling pathways [15]. The first chemical has been mentioned before — dopamine. The paper suggests that dopamine is released when we are made aware of opportunities that would fulfill our needs, and achieves its effects by giving us the energy to pursue them. The alternative example provided in the paper is training for a marathon since the steps taken by the runner are neurally linked to a reward and the brief spurts of dopamine are secreted for a long period of time.

Another chemical that the paper discusses is oxytocin, associated with the feeling we experience as "trust." Exposure to an uncontrolled array of people and interactions on social media can bombard this system as well, and the paper suggests a focus on building deeper trust bonds. Meeting two very close friends regularly is more likely to stimulate the release of oxytocin than a larger group that is less familiar. Finally, serotonin is a neurotransmitter that causes you to experience an elevated mood, specifically when you feel you have performed a given task well. Seeking to perform well on tasks that reward well in the short term should provide a healthy release of serotonin. Activities that stimulate the release of neurotransmitters in a more controlled manner, such as in the examples above, are considered "energizing hobbies" and could serve as a replacement for internet use when resting [15].

The highlights of this article could be transcribed from a call with your mother — spending too much time on your device is bad for you, so you should go out in the real world more. However, given that the internet is a relatively new element of human life that is only becoming more important with time, it is important to be mindful of the effect it has on the brain to utilize it in a controlled and beneficial way. ♔

Seeing Double

by Sabrina Hsu
art by Caitlin O'Neil

As a 19th-century Irish housewife, Bridget Cleary raised eyebrows—in life and especially in death. Beautiful, unconventionally independent, and possessing entrepreneurial savvy, she lived apart from her husband, Michael, and ran her own business as a seamstress and hatmaker [1]. When Bridget went missing in March 1895, there was something odd about Michael's behavior—perhaps his agitated need to confess to a priest or the mournful vigils for a wife he claimed ran away—which led police to suspect foul play. After scouring forests and dragging creeks to no avail, one sergeant stumbled upon incongruously hacked thorn bushes in a field. There, beneath the shrubbery and a thin layer of clay, lay Bridget Cleary. Unclothed aside from her stockings, Bridget's corpse bore nightmarish marks of violence [1]. How did this happen?

The full story emerged after Michael Cleary and other suspects were put on trial for murder. In early March, Bridget fell ill with bronchitis, an inflammatory lung infection that was the main cause of mortality in England at the time [2]. Her condition worsened so rapidly that her father sent for a doctor and her husband a priest [3]. As Bridget's condition deteriorated, Michael not only refused her all prescribed medicine but further administered increasingly horrific folk "remedies." Along with several accomplices, Michael forced Bridget to consume vile, ineffective concoctions, doused her with urine, and then strangled and burned her to death. Why? Per testimony from the group of perpetrators, those acts of torture were an exorcism [3]. They believed that the "real" Bridget had been supplanted by a changeling—an identical impostor left in place after an individual is abducted by faeries [4].

While that may seem an outlandish claim from a modern perspective, changeling myths are deeply rooted in Irish folk culture [5]. Variations of the changeling archetype appear in traditional tales throughout Europe. Irish faeries, Slavic Mamuna spirits, Nordic trolls, Spanish Xanas nymphs, and more have all been depicted to kidnap humans in exchange for one of their own [6, 7]. The abducted individuals are usually young adults or children. This recurrent theme may have stemmed from the belief that young people are particularly vulnerable to demonic possession, especially when unbaptized [8].

Today, Bridget Cleary is retrospectively (and rather inaccurately) known as the last witch burned in Ireland. Her husband's motives remain a subject of debate. Was Michael threatened by his wife's autonomy, self-reliance, and probable reluctance to obey his every whim? Was he a painfully superstitious zealot? Although history has left this unanswered, neuroscience has provided a plausible working theory. In 2006, a paper published in the Irish Journal of Medical Science was the first to suggest a psychiatric origin for Michael Cleary's actions: Capgras syndrome [4].

Capgras syndrome is a rare but intriguing psychological condition where a person becomes wholly convinced that a close family member, friend, or even pet has been displaced by a physically indistinguishable substitute [9]. Although doppelgänger takeovers have long ensnared the imagination, a recurring motif notably reimagined in Jordan Peele's *Us*, the precise mechanics underlying Capgras syndrome remain obscure. This elusive disorder is named after Joseph Capgras, the first psychiatrist to chronicle its symptoms, who aptly termed it "l'illusion des sosies" (illusion of doppelgängers) [10]. In his pioneering article, Capgras records the remarkable case of Madame M., who insisted that her husband had been murdered and replaced

by over 80 disparate impostors over ten years [10]. While Madame M. represents an astonishing figure as the inaugural Capgras patient in academic literature, the delusion is not always as intense and may even be temporary [11].

A wide range of medical conditions have been linked to Capgras syndrome, which further complicates attempts to pinpoint a common causal factor. For instance, Capgras delusions are sometimes observed in dementia patients [12]. However, researchers have found that the prevalence of Capgras symptoms differs among various dementia classifications: two types of dementia (Alzheimer's and Lewy body) exhibit the hallmark misidentification problems of Capgras Syndrome, while another type (frontotemporal) does not [13]. Although this distinction makes isolating the brain structure that causes Capgras syndrome even harder, it still offers some neurological insight. Alzheimer's and Lewy body dementia are both closely associated with severe hippocampal degeneration [14, 15]. The hippocampus, an area of the brain heavily involved in memory consolidation and emotional processing, is indispensable in infusing memories with emotional color [16]. As hippocampal deterioration takes center stage for Alzheimer's and Lewy body dementia patients, memory loss becomes more severe [17, 18]. This can increase the risk that an individual will experience an inability to associate emotions with familiar faces [17, 18]. Given that this inability is a core attribute of Capgras syndrome, scientists have hypothesized that Capgras delusions occur when the hippocampus breaks down, causing the connection between memory and emotion to weaken [9].

To put it simply, scientists suggest that for your brain to identify your naughty little brother correctly, it needs to (a) recognize him and (b) experience a subconscious emotional response, whether it be doting fondness or nagging annoyance [19]. When the connection between those two steps is severed by Capgras syndrome, your brain fails to confirm the identity of your brother due to a lack of emotional familiarity, possibly causing you to experience a kind of emotional blankness and bewilderment [20]. Therefore, you may believe he is an impostor even though your brain recognizes that he looks and acts just like your brother. Imagine gazing at your long-time partner and feeling like they're a complete stranger, or looking at your mom and feeling certain she's been replaced by someone who looks eerily similar. This is undoubtedly a disorienting and alarming experience and can be potentially harrowing for both the individual with Capgras syndrome and their loved ones.

Imaging studies of selectively damaged brain regions, or lesions, have allowed scientists to identify several brain areas heavily impacted by Capgras syndrome [21]. One of these regions is the fusiform face area (FFA), a blueberry-sized region specializing in facial recognition [22]. When someone's FFA is damaged, they may have difficulty recognizing familiar faces, a condition known as prosopagnosia or facial blindness [23]. As issues with recognition also mark Capgras syndrome, this raises the question: is Capgras syndrome simply a manifestation of prosopagnosia? Evidence suggests this is not the case; the recognition issues associated with prosopagnosia and Capgras differ [9, 23]. Unlike individuals with prosopagnosia, who are unable to recognize facial features, Capgras patients can recognize facial features—however, when they do, they are under the impression that these features have been perfectly duplicated [9, 23]. Moreover, facial blindness alone should not automatically make one suspect nefarious impostor activity [24]. This suggests that Capgras syndrome cannot solely be traced back to damage to the FFA, bringing us to another brain region associated with Capgras syndrome: the amygdala [22]. An almond-shaped cluster of cells, the amygdala is an area involved in processing emotions such as fear and anxiety [22]. Patients with Klüver-Bucy syndrome, which is linked to amygdala injury, exhibit behaviors marked by an unnatural state of zen and a near-complete lack of fear [25]. This disposition contrasts completely with the anxious distrust elicited by Capgras syndrome. Altogether, prosopagnosia and Klüver-Bucy symptoms suggest that neither FFA nor amygdala dysfunction alone can induce Capgras delusions [25].

It appears that a more promising approach for deciphering Capgras delusions lies in analyzing the exchange pathways that bridge the FFA and the amygdala [22]. When we perceive a face, visual stimuli undergo specialized processing in the temporal lobe, the neural structure overseeing emotional, sensory, and linguistic signals [26]. Within the temporal lobe, the FFA manages facial information and interfaces with the amygdala to assess the emotional significance of each face [22]. Capgras syndrome effectively disrupts these connecting pathways, disabling informational exchange between the FFA and the limbic system. These findings support the idea that an interruption in the normal processing of visual and emotional information is a driving force behind Capgras delusions, resulting in a disconnect between visual and emotional familiarity [22]. When the brain can no longer allot emotional value to a visually recognized face, a sort of cognitive dissonance may occur, forcing the individual to view the person in front of them as an imitation, a fraud [27].

In addition to certain forms of dementia, episodes of Capgras delusions have been documented in conjunction with a wide range of conditions, including epilepsy, multiple sclerosis, and AIDS [28]. Among its diverse co-diagnoses, Capgras syndrome seems especially connected to schizophrenia, a mental disorder where psychosis episodes can distort the perception of reality [29]. A review of 255 Capgras cases showed a 32% overlap with schizophrenia diagnoses [24]. The specific neurological common ground joining the two remains unclear, though scientists are pursuing right frontal lobe damage as a possible contender [30]. Greater progress has been made by studying Capgras patients whose symptoms arose in concert with traceable brain damage, such as those due to traumatic injuries, a stroke, or carbon monoxide poisoning [11].

Due to the lack of a universally accepted cause for the disorder, a cure for Capgras syndrome has yet to exist. For individuals whose Capgras delusions are a symptom of other disorders, prescribed treatment often involves medications that help address the underlying condition; these may include antipsychotic drugs for those with schizophrenia or neurotransmitter boosters for those with dementia [31]. The former helps reduce occurrences of hallucination or severe agitation, while the latter temporarily strengthens some cognitive functionality, such as memory [32, 33]. Cognitive behavioral therapy, a form of talking intervention designed to help people recognize their own negative or inaccurate thoughts, can also help patients question and challenge their impostor beliefs in a safe and supportive environment [34, 35].

Researchers are focused on better understanding the disorder's neurobiological underpinnings and identifying effective treatments [36]. One area of current research is the application of transcranial magnetic stimulation (TMS) to stimulate the FFA and other affected regions [36]. TMS is a non-invasive technique that uses magnetic fields to stimulate the brain [37]. Research indicates that TMS might help improve facial recognition in individuals with Capgras syndrome by modulating the activity levels of impacted areas, but its effectiveness is still being investigated [36]. Despite a lack of targeted treatments for Capgras patients, it is crucial to recognize that Capgras syndrome is a debilitating condition that can shatter one's quality of life. Individuals diagnosed with Capgras syndrome aren't just being stubborn or difficult—they're experiencing a physiological disruption in their brain's ability to recognize and attach emotions to familiar faces. However, with adequate support and palliative care, they can learn to manage their symptoms and live fulfilling lives.

The tragedy of Bridget Cleary underscores the importance of understanding and addressing the neurological conditions that could have induced Michael Cleary's irrational beliefs. Capgras syndrome offers a scientific explanation for the delusions that may have played a role in Bridget's horrific fate. While the specific circumstances of Bridget's case may never be fully known, it's clear that undiagnosed and untreated neurological conditions can have serious consequences. By studying conditions like Capgras syndrome and promoting awareness of their

symptoms and effects, we can work toward an enhanced comprehension of the brain to prevent similar tragedies in the future.

It is also crucial to recognize that while Michael Cleary may have been experiencing delusional beliefs associated with Capgras syndrome, his accomplices were likely influenced by a phenomenon known as groupthink. Groupthink occurs when individuals feel pressured to conform to the opinions and decisions of a group, even when those decisions may be flawed or irrational [38]. In the case of Bridget Cleary, the groupthink mentality may have contributed to the escalation of violence and the failure of the accomplices to question Michael's maniacal behavior. Additionally, we may presume that the group's actions were influenced by the prevailing misogynistic views of the time period. Bridget was unique for her era as a woman possessing beauty and independence in equal measure. Her success as a businesswoman and her defiance of traditional gender roles may have been perceived as threats to the patriarchal hierarchy. The group's willingness to believe Michael's claims and participate in the abuse of Bridget may have also been a manifestation of their learned biases and personal insecurities.

Ultimately, this case is a sobering example of how a combination of factors—including neurological conditions, groupthink, and societal bias—can lead to catastrophic outcomes. By analyzing the complex interplay of these factors, we can gain a deeper understanding of the sociocultural forces that shape our perceptions of difference and inform our actions toward those who are perceived as "other."

Are you a witch or
Are you a fairy?
Or are you the wife
of Michael Cleary?

So goes an Irish nursery rhyme immortalizing Bridget Cleary [39]. In Bridget's case, her story's tragic outcome highlights the dangers of misunderstanding neurological conditions and instead attributing them to supernatural causes. The concept of changelings in Irish folklore was often used to explain behavior that was considered unusual or abnormal, and this belief had devastating consequences for individuals like Bridget, who were perceived as different [8]. Regardless of the geographic source, changeling myths have been used to justify ableist abuse, abandonment, and murder before a scientific understanding of disability was normalized [8]. After all, many of the monsters in stories represent human fears of the unknown [40]. Changelings were sometimes described as exhibiting behavior evocative of neurodivergence [41]. For instance, changelings may display intellectual or behavioral tendencies incongruent with their age and physical characteristics, like fidgeting or unexpected vocalizations [41]. Therefore, some scholars suggest that changeling stories were conceived to reflect prejudice against those with autism, ADHD, dyslexia, Down syndrome, and more [8].

> "*They believed that the "real" Bridget had been supplanted by a changeling—an identical impostor left in place after an individual is abducted by faeries.*"

Modern manifestations of changeling fears are rooted more in jest than malice. Today, the narrative archetype lives on as doppelgänger conspiracies, tongue-in-cheek accounts of Avril or Kanye being replaced by lookalikes. These "theories" may be amusing internet fodder, but Bridget's story demonstrates that the concept of impostor doppelgängers can have serious consequences in the real world. For individuals with conditions like Capgras syndrome, the delusion that an identical stranger has replaced someone familiar is their lived reality. So, while the idea of celebrity clones running amok makes for entertaining blog posts, it should also serve as a reminder of the uncharted complexity of the human brain and how it can shape perceptions of the world that differ from individual to individual. Overall, Bridget Cleary is a cautionary tale about the dangers of misunderstanding neurological conditions. Through continued research and education, we can challenge social prejudice, bolster awareness and understanding, and ultimately improve the lives of those affected by neurological disorders. And hey, maybe we can even debunk some celebrity doppelgänger conspiracies along the way! ♔

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