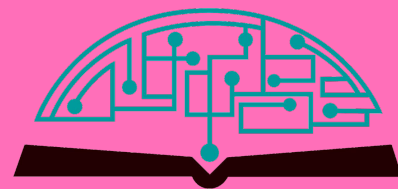


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A Drone-Based AI Solution for Smart Park Management

Austin Zhang

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ABSTRACT: San Diego's Black Mountain Open Space (BM) Park struggles with the severe challenges of wildfire and vegetation management because of its largely inaccessible 2,350-acre terrain and rugged environment. This project proposes a drone-based, Artificial Intelligence (AI), and Geographic Information System (GIS) integrated system to address these challenges. The system applies high-resolution drone imagery analyzed by AI algorithms to identify dry plants, seedlings, and fire-prone zones automatically. It uses GIS to interpret the imagery and produce 2D and 3D terrain mapping for further analysis, which will enable park rangers to preempt fire-prone areas and monitor dry plants, seedlings, and invasive species. The system can also be used in real-time video detection to aid decision-making and improve response time. The results showed that the Drone-AI-GIS integrated system is capable of scanning massive areas at least five times faster than manual labor while also providing actionable information in real-time for the park ranger to act, and that the system can be easily adapted to other parks or scaled to a much larger application area.

KEYWORDS: Environmental Science, AI Technology, Wildfire Mitigation, Vegetation Management, Drone Imaging.

■ Introduction

Drone imagery and AI have been leveraged for vegetation and fire risk monitoring.¹⁻⁴ For example, Turner et al. utilized drones equipped with multispectral cameras to monitor the health and distribution of vegetation in environments that are challenging to access using traditional methods;¹ Zhang et al. showed that AI models are highly able to automatically detect fire-prone zones in real-time by incorporating surrounding environmental factors such as wind, humidity, vegetation status, and can help predict and identify fire outbreaks with high accuracy.² However, even though those studies show the advantages of drone technology and AI respectively, what is lacking in the currently available research is a fully integrated system that combines the power of drones, AI, and GIS for smart park management that is capable of 3D GIS mapping, real time video detection, AI driven fire risk mitigation, detailed GPS logging and future automation. By integrating those technologies, this proposal will not only improve short-term operational efficiency but also ensure long-term sustainability in park management, allowing for better monitoring of the health of plants and more effective mitigation of wildfire risks.

BM Park's over 2,350 acres of rugged land have been facing severe challenges in vegetation management and wildfire risk mitigation due to its dense vegetation and highly diversified terrain. Currently, park rangers and volunteers are forced to rely on manual methods to monitor the vast majority of the park to identify the areas that require planting, watering, or attention for wildfire risks. However, these manual methods are time-consuming, labor-intensive, and often unsafe, especially in the vast majority of the unwalkable areas. On top of these challenges, BM Park is classified as a Very High-Risk Fire Zone by Cal Fire,⁵ and thus there is an urgent need for fire risk monitoring.

Given these challenges, traditional methods of vegetation management and fire risk mitigation are no longer feasible. Manual monitoring done by park rangers and volunteers cannot keep up with the rapidly growing needs of the park, the complexity, and the diversified terrains. The current approach is to walk through the park's massive terrain and rugged terrains, check plant health status, identify invasive species, dry plants, and locate areas of stressed plants and seedlings' health. This approach is not only highly labor-intensive but also dangerous, especially when dealing with vast areas, steep slopes, and vegetation-dense areas and invasive species.

Aware of the inefficiency of the manual approach and given the rising challenges, I decided to develop a technical solution to address these rapidly growing problems. In this project, I propose a drone-based, Artificial Intelligence (AI), and Geographic Information System (GIS) integrated system to address the challenges of both vegetation management and wildfire risk monitoring at BM Park. This integrated system utilizes high-resolution drone imagery, GIS technology to map out terrain, and AI-based analysis to automate the detection of dry plants, invasive species, and fire-prone zones.

■ Methods and Procedure

Traditional manual monitoring methods suffer from inefficiencies and safety concerns. A new system was designed to address those limitations while also enhancing the overall effectiveness of park management. The methods used to address the objective include Drone design, AI model design, and the use of GIS for 2D and 3D terrain mapping.

Initial Planning and Setup:

The first phase involved an initial survey of the park to determine areas with severe vegetation issues and wildfire-prone risk zones. Based on the results, certain regions of the park were

Machine Learning-Assisted Prediction of Variant Pathogenicity in Neuro-Genetic Disorders

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ABSTRACT: Neurological disorders and their underlying genetic causes continue to be vastly unexplored. However, with the advent of technology, there is an increased scope for analyzing at the genetic level by looking at variants, cell functions, and risk alleles. In this study, from the GWAS (Genome Wide Association Study) catalogue and existing data sets from studies, single-nucleotide variants (SNVs) in terms of risk allele, mapped genes, traits, and p-value associated with specific neurological disorders were collected, followed by gene and variant identification. Using network and pathways analysis software STRING, Cytoscape, and the Reactome database, top genes were identified. The risk alleles associated with the genes of SNVs were taken and input into Ensembl's Biomart and annotated in Ensembl's VEP (Variant Effect Predictor). This collated information helped in gaining more information about the associated SNVs and helped identify the impact of these variants on the disorders. The ML models, RidgeCV and HuberRegressor, trained on the variant annotated dataset to make a risk score prediction system and classification system, achieved highly accurate results. This prediction system can significantly aid in clinical and scientific analysis, which, in the future, may result in the betterment of patient care and treatment.

KEYWORDS: Neurological Disorders, Machine Learning, Structural Variants, Single Nucleotide Variants, and Risk Scoring.

■ Introduction

Neurological disorders, in summary, are all conditions related to the central and peripheral nervous system. These disorders can be categorized in countless ways. A few categories include neurodegenerative, neurodevelopmental, neuromuscular, neuropsychiatric, seizure, cerebrovascular, and infectious disorders. According to the World Health Organization (WHO), neurological disorders are the second leading cause of death¹ with approximately 9 million deaths annually.² In India specifically, there is a huge prevalence of neurological disorders as per the Indian Council for Medical Research (ICMR). An example is India's contribution of 20 percent of the global cases of epilepsy.³ There are a lot of external and internal factors that influence these disorders, but their causes are still a vastly uncharted domain.

In the small sample size of research for this project, it was discovered that most studies focused on uncovering the genetic causes of specific symptomatic neurological disorders. For instance, in a study of muscular system atrophy, they identified novel risk loci,⁴ or in a study of Alzheimer's, where they tried to understand the SNPs and their impact on proteins.⁵ Additionally, in a study about Amyotrophic lateral sclerosis(ALS), they uncovered changes in terms of structural variations across 25 known ALS genes,⁶ and in research about Multiple sclerosis, they identified 10 candidate nsSNPs and assessed their functional impact.⁷ In a study about Dyslexia,^{8,9} Childhood Apraxia of Speech (CAS),¹⁰ and Intellectual Disabilities,¹¹ they performed wide genome analysis and identified ¹² pathogenic or likely pathogenic variants in key developmental genes. The

diversity and complexities of such conditions allow for a lot of scope for research in this area of mental health illnesses.

Research into the genetic architecture of neurological disorders is expanding. Studies have found multiple genetic variations and mutations, such as structural variants (SVs), single-nucleotide variations (SNVs), short tandem repeat (STR) variants,¹² and copy-number variants in the exome that could suggest pathogenic properties with respect to these disorders. With the rise of multiple bioinformatics tools and Genome Sequencing technology like Oxford Nanopore PromethION platform,¹³ SV/CNV calling (Sniffles, CuteSV), Pathogenicity prediction through PolyPhen-2, SNPs & Go, PredictSNP, variant sourcing from the NHGRI-EBI GWAS Catalog, Ensembl VEP to characterize variant effects, and so many more, our understanding has broadened.

With reference to the research collected, it was understood that there was no clear method that could be used to identify risk alleles and variants, and which disorder they could lead to. Understanding if there are monogenic risk loci that are associated with such conditions can help in the early diagnosis and treatment of patients in this age range, also preventing any further neurological deterioration or reduced development. Therefore, the hypothesis for this study is to analyze existing databases and determine if there are monogenic causes in the form of structural variants and single-nucleotide variants for neurological disorders, and create a detection system that can show from a given dataset whether the risk allele or variant provided can be benign or malignant.

Smart Photocatalytic Self-Cleaning Urinal System for Public Hygiene & Sustainable Sanitation

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ABSTRACT: Public sanitation facilities in India, particularly high-footfall public urinals, continue to face persistent challenges, including microbial contamination, unpleasant odors, irregular maintenance, and inefficient water usage. These issues increase public health risks, discourage usage, and limit the effectiveness of national sanitation initiatives such as the Swachh Bharat Mission. The COVID-19 pandemic further highlighted the need for preventive, hygiene-focused sanitation solutions that reduce human contact and dependence on manual cleaning. To address these challenges, an IoT-based Smart Photocatalytic Self-Cleaning Urinal System was developed that integrates titanium dioxide (TiO_2) – based photocatalysis, ultraviolet (UV) disinfection, and a microcontroller-based automated system for sustainable sanitation. A TiO_2 nano-coated surface activated by UV-A illumination (365–385 nm) generates reactive oxygen species that decompose organic residues and neutralize ammonia-based odors, while complementary UV-C exposure (200–280 nm) ensures effective microbial inactivation by disrupting bacterial and viral DNA and RNA. The system incorporates an ESP32 microcontroller, a Time-of-Flight (ToF) sensor, UV LEDs, a two-channel relay module, an ammonia (NH_3) gas sensor, a DHT11 temperature and humidity sensor, a DFPlayer Mini audio module with speaker, a water flow sensor, an ultrasonic sensor, and a solenoid valve. System operation is managed by the ESP32 microcontroller, enabling Time-of-Flight-based user detection, safety-controlled UV activation, and a touchless solenoid valve-based flushing mechanism. Parameters such as temperature and humidity, ammonia concentration, water flow, user count, and tank water level are continuously monitored to support real-time hygiene assessment, water leak detection, water availability monitoring, and optimized system performance. The DFPlayer Mini audio module delivers automated voice announcements to guide users, promote hygiene awareness, and encourage proper usage, thereby supporting improved public sanitation practices. The ESP32 microcontroller is programmed using the Arduino IDE. A web-based dashboard has been developed to monitor urinal vacancy status, user count, temperature, humidity, hygiene status (based on NH_3 levels), UV light ON/OFF status, flushing status, water leakage and consumption, and tank water availability using ultrasonic sensing. The dashboard also allows customization of flush cycles and flush activation distance. The proposed system demonstrates the potential to improve hygiene standards in public urinals through continuous self-cleaning and self-disinfection, reduced water and chemical usage, minimized manual intervention, and remote monitoring, with alerting capabilities. This can be further upgraded into a scalable and sustainable solution for enhancing public sanitation infrastructure and improving user experience in public spaces.

KEYWORDS: Photocatalysis, Titanium Dioxide (TiO_2), Self-cleaning Surfaces, Sustainable Sanitation, Internet of Things (IoT).

■ Introduction

Field observations conducted during visits to public toilets in cities such as Vijayawada (Figures 1, 2, 4) and Guntur (Figure 3), as well as sanitation facilities encountered during railway travel, shopping malls, and bus stations, revealed consistently poor hygiene conditions. Common issues identified include persistent foul odors, inadequate maintenance, manual flushing systems, non-availability of water, water leakages, lack of supervision, excessive use of cleaning chemicals, and high chances of microbial contamination. Due to these unhygienic conditions, many individuals avoid using public urinals and instead resort to open urination, which further aggravates environmental pollution and public health risks. Access to safe and hygienic sanitation facilities is a critical determinant of public health and human dignity.

To address the issue of open defecation, the Government of India launched the Swachh Bharat Mission in 2014. Un-

der this initiative, more than 6,36,826 community and public toilets¹ were constructed across the country. This program has significantly improved sanitation infrastructure nationwide. However, the hygienic maintenance of public urinals continues to remain a persistent challenge. To ensure that these efforts are sustainable and effective in the long term, it is essential to adopt smart technologies that simplify the operation, maintenance, and supervision of public sanitation facilities.



Figure 1: Unhygienic Surroundings. **Figure 2:** Excessive use of chemicals.

Breaking the Glass Ceiling: Addressing Low Female Participation in the Indian Hospitality Industry – A Case Study with Specific Reference to a Four-Star Hotel in Bangalore

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ABSTRACT: Using a mixed-method data collection approach, this study analyzes the implications of low female labor force participation in the hospitality industry in India. The findings of this study reveal low participation rates, with women comprising only 20% of the total workforce in the sector. Most female employees were concentrated in front-facing, lower-paying roles and were underrepresented in executive positions. At the Royal Orchid Hotel in Bangalore, only nine of the 34 executive positions were held by female employees. Workplace biases intertwined with strict regulations (night shift laws) create significant challenges for female employees. Interviews with six employees (3 male, 3 female) in the Royal Orchid Hotel, Bangalore, revealed several societal and personal barriers that hinder long-term career retention. Employees highlighted work-life balance challenges: Significant family responsibilities are placed on women in India. Quantitative data collected revealed the presence of gender-based wage disparities: Females earned a mean salary of ₹22,940, while the average workplace wage was ₹33,147 monthly. Findings suggest that policy reforms, flexible working hours, and targeted skill development programs are essential to increase female participation in the sector.

KEYWORDS: Hospitality Management, Labor Economics, Public Policy, Gender Studies, Employment and Labor Relations.

■ Introduction

Indian households struggle to meet basic financial requirements, with some men required to work two jobs to support their families. Some Indian women are full of ambition but are often handicapped when entering the workforce, as countless Indian women lack a high-level education. Although many industries require higher-level qualifications, the hospitality industry presents a lower educational threshold. Still, female participation remains low. According to the Ministry of Statistics and Programme Implementation (2023), women constitute only 30% of India's hospitality workforce compared to the global average of 46%, despite lower barriers to entry in this sector.¹ This study will investigate the socio-economic factors contributing to low female labor force participation in the hospitality industry. The hospitality industry is vital to India's economy, contributing 9.4% of the nation's GDP and employing 8% of its workforce.¹ Despite the industry's economic significance, it fosters stark gender disparities, with men disproportionately occupying managerial roles while women remain in lower-paying frontline positions. Furthermore, women only constitute 30% of the Indian hospitality workforce, compared to the global average of 46%.² This disparity raises concerns about socio-economic obstacles that restrict the participation of women in the hospitality industry and the workplace as a whole in India.

To identify and observe the stark gender disparities in the rising industry, this paper answers the question: What socio-economic factors contribute to the low female labor force participation in the Indian hospitality industry? It examines

the socio-economic factors contributing to the low female employment rates evident in the Indian hospitality industry. It uncovers the socio-economic roots of disparity: employer biases, physical constraints, regulatory challenges, social taboos, and more. Moreover, it highlights the relationship between development and women's participation in the workforce. The study relies on a mixed data collection approach, collecting quantitative and qualitative data from the Royal Orchid Hotel, Bangalore. Qualitative data were collected by interviewing executive directors and staff members to understand the gender-based narratives in the hospitality industry. Quantitative data were collected by accessing the hotel's database, and key statistics regarding gender disparities, such as attrition rates, were extracted. Based on the literature review conducted, several research gaps were identified, specifically around regulatory restrictions in the industry, regional participation factors, and barriers in skilling programs. To address these gaps, the study aims to pursue the following objectives: (1) identify occupational segregation in an active Indian hotel (Royal Orchid Bangalore), (2) analyze how India-specific regulations, such as night shift restrictions, influence wage disparities between genders, and (3) provide original case-based examples of the struggles female employees face while participating in the sector.

Addressing this issue is crucial. With the demand for hospitality rising, gender inclusivity can drive economic growth while promoting the rapid expansion of the hospitality industry. Through an amalgamation of a literature review, qualitative data, and quantitative data collection, the study will contribute

Adaptive Bandwidth Allocation for Sub-THz and Terahertz Wireless Links

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ABSTRACT: Future 6G wireless systems are expected to exploit sub-terahertz (sub-THz) and terahertz (THz) frequency bands to enable extremely high data rates. However, these bands suffer from severe propagation losses due to free-space path loss, molecular absorption, blockage, and hardware limitations. This project proposes adaptive bandwidth allocation as a practical mechanism to improve link reliability by concentrating transmit power over a reduced bandwidth when channel conditions degrade. The study, analysis, and conclusion are based on simulation and theoretical data.

KEYWORDS: Wireless Communications, Terahertz Communication, 6G, Adaptive Bandwidth, Uplink Limitation.

■ Introduction

THz communication offers a large bandwidth but experiences extreme attenuation, limiting coverage and reliability, particularly in uplink-limited scenarios.¹ This study independently models the impact of adaptive bandwidth allocation on uplink-limited sub-THz links using MATLAB simulations. Unlike prior survey-based work, this paper quantitatively demonstrates how bandwidth reduction improves per-resource-element power, SINR, and BLER under realistic UE power constraints. This study primarily focuses on uplink-limited performance in sub-THz and THz systems under strict UE transmit power constraints, while downlink is discussed as a secondary consideration. Unlike prior adaptive sub-band allocation studies that primarily address spectrum efficiency or throughput optimization, this work is explicitly for per-resource-element power concentration under fixed UE transmit power.

■ Results and Discussion

Background and related work:

Propagation at terahertz frequencies is dominated by free-space path loss, which increases quadratically with carrier frequency.² Even over short distances, this results in significant signal attenuation.

In addition, molecular absorption by atmospheric gases such as water vapor and oxygen introduces frequency-selective attenuation,³ creating usable transmission windows separated by absorption peaks. Environmental factors such as humidity, rain, and fog further exacerbate signal degradation.

Due to the extremely short wavelengths, THz signals exhibit poor diffraction around obstacles and experience severe penetration loss through common materials. As a result, reliable non-line-of-sight communication is extremely challenging.

In cellular systems, uplink communication is inherently constrained by user equipment (UE) transmitting power limitations. At THz frequencies, the use of extremely wide

bandwidths significantly increases the receiver noise floor, further degrading uplink performance.⁴

Unlike base stations, UE devices are limited in antenna size, beamforming capability, and thermal dissipation. These constraints make uplink coverage one of the most critical bottlenecks in THz-based cellular architecture.

The following plots provide insight into expected terabit-per-second data rates and the available frequency bands within the terahertz spectrum.

The evolution of peak data rates for cellular and Wi-Fi technologies is shown in Figure 1, while the electromagnetic spectrum and the terahertz frequency bands are illustrated in Figures 2 and 3, respectively.

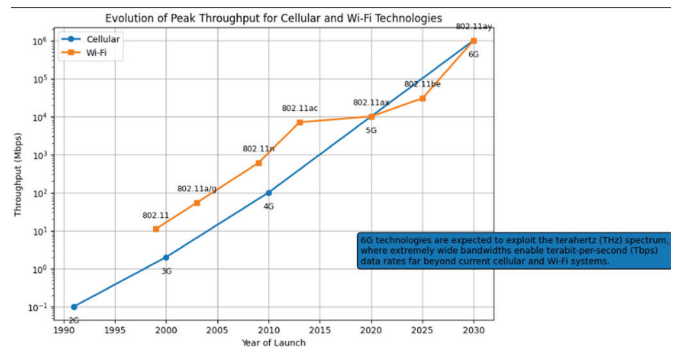


Figure 1: Evolution of peak data rates for cellular and Wi-Fi technologies. The figure highlights the exponential growth in peak data rates over successive generations, motivating the need for sub-THz and THz spectrum utilization in future 6G systems.

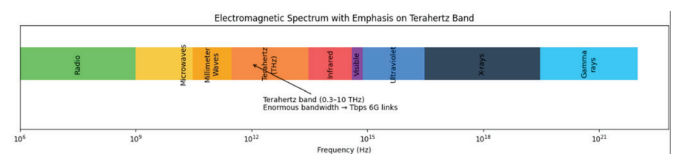


Figure 2: Electromagnetic spectrum. This figure situates the terahertz band between microwave and infrared frequencies, illustrating its potential for ultra-wide bandwidth communications.

Differences in Microglial Colocalization with Amyloid- β in Patients with Dementia Using the SEA-AD Dataset

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ABSTRACT: Alzheimer's Disease (AD) is marked by cognitive decline, neurodegeneration, and the formation of amyloid-beta ($A\beta$) plaques and tau tangles. AD is the most common form of dementia, which is an umbrella term used to describe a decline in cognitive ability that affects daily life. This study is focused on differences in colocalized $A\beta$ and microglia in the brains of 84 individuals, 42 diagnosed with dementia, and 42 without a diagnosis of dementia. Analyses of neuropathological data from the SEA-AD dataset found that there is a greater amount of colocalized 6e10 and Iba1 objects— markers for $A\beta$ and microglia, respectively – in patients diagnosed with dementia, and less from patients with no diagnosis of dementia. In dementia, the degree of Iba1-6E10 colocalization varied across cortical layers, with more colocalized objects in layers 3 and 5/6. Notably, layer 3 showed the greatest increase compared to layer 5/6. This suggests that microglial colocalization of $A\beta$ plaques is most pronounced in layer 3, offering insight into layer-specific microglial activity in Alzheimer's disease.

KEYWORDS: Biology, Neuroscience, Alzheimer's Disease, Neuropathology, Microglia.

■ Introduction

Alzheimer's disease (AD) is a disease marked by cognitive decline, neurodegeneration, and the presence of amyloid-beta ($A\beta$) plaques and formation of tau tangles. It is the most common form of dementia, an umbrella term used to describe a decline in cognitive ability that affects an individual's daily life. Microglia, which are phagocytic immune cells of the brain involved in regulatory processes critical for development, maintenance, and repair,¹ have an intriguing relationship with AD, and in turn, $A\beta$, that has yet to be entirely understood.^{2,3}

Colocalization of microglia with $A\beta$ plaques in AD has been previously associated with microglia's role in clearing and metabolizing the plaques, as was found by Van Olst *et al.*⁴ Escario *et al.*⁵ conducted a similar analysis of colocalized $A\beta$ and microglia in AD, but correlated it also to changes in global cognitive abilities. They found that higher expression of colocalized $A\beta$ and microglia correlated with lower cognitive abilities, and therefore, the amount of colocalized objects was consistently higher in concentration in AD patients than in controls.

The present study aims to examine how colocalized microglia and $A\beta$ in different cortical layers correspond with the incidence of dementia through analyzing quantitative neuropathological data from the open-source SEA-AD dataset.^{6,7} The data were collected from the middle temporal gyrus (MTG) of 84 patients, evenly split between cohorts of patients presenting with and without the cognitive and behavioral deficits of dementia. The patients' Alzheimer's Disease Neuropathologic Change scores ranged from 9 with No AD, 12 Low, 12 Intermediate, and 42 High. The MTG is a region that is of great importance to cognitive functions such as language processing and semantic memory, and is also one of the first to be targeted in disease development. The identification of cortical

layer-specific patterns of $A\beta$ -microglia colocalization in the data can yield a greater understanding of which types of tissue and cells are implicated in the aggregation of these pathologies. This study hypothesized that there would be significant differences between the amount of colocalized microglia and $A\beta$ between individuals with and without dementia.

■ Methods

The SEA-AD open-source database, containing detailed neuropathological, genomic, transcriptomic, and demographic data from post-mortem brain tissue samples of 84 donors, half of whom were affected by Alzheimer's Disease was used.⁸

SEA-AD Participant Recruitment:

The brain specimens used to create the SEA-AD database were obtained from the Adult Changes in Thought (ACT) Study and the University of Washington Alzheimer's Disease Research Center (ADRC) Clinical Core study.⁸

For the ACT study, participants were invited to enroll at age 65 by random selection from the patients of KPW Seattle and undergo study visits twice a year for physical and mental examinations. About 25% of ACT donations were from people with no MCI or dementia at their last evaluation; 30% met criteria for MCI, and 45% met criteria for dementia.⁹

Patients enrolled in the UW ADRC Clinical Core underwent annual study visits, including identical mental and physical exams to those conducted in the ACT study, as well as donations of biospecimens that included blood and serum, and family interviews.¹⁰

Individuals with a diagnosis of frontotemporal dementia, frontotemporal lobar degeneration, Down syndrome, amyotrophic lateral sclerosis, or other confounding degenerative disorder (not including Lewy Body Disease or VBI) were

Absolute Pitch: Interplay of Genetics, Brain Structure, and Early Experience

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ABSTRACT: Absolute pitch (AP) is the rare ability to identify or produce musical notes without an external reference. The origins of AP remain debated. In this review, we integrate evidence across genetics, brain structure and function, and early experience. Work in vocal-learning animals and human genetics points to gene networks, including *FoxP2* and downstream partners, that shape the cortico-striatal circuits required for precise auditory-motor mapping. Structural and functional imaging in humans shows differences in the planum temporale and adjacent auditory cortex in individuals with AP, often with stronger leftward asymmetry and altered microstructure, consistent with early-tuned category representations for pitch. Behavioral and developmental studies in humans indicate that early music training and exposure to tonal languages increase the likelihood and stability of AP, in line with a sensitive-period account and with learning-by-labelling mechanisms. Taken together, AP most likely arises from the interaction between biological predisposition and structured early input. Genetic programmes establish circuits with high resolution for pitch, and early labelling experiences consolidate these circuits into a durable skill. We outline key gaps, including causal links in humans, cross-species generalisation, and measurement heterogeneity, and propose longitudinal and interventional designs to resolve mechanisms and to test gene-environment models.

KEYWORDS: Neuroscience, Cognitive Neuroscience, Absolute Pitch, Auditory Perception, *FoxP2* Gene.

■ Introduction

Absolute pitch (AP) is a striking yet uncommon human ability. Some individuals can identify or produce a musical note with no external reference, an ability that continues to intrigue neuroscience and cognitive science. Its rarity, its apparent effortlessness in expert listeners, and its tight link between perception make AP a natural target for theories of auditory cognition.^{1,2} Operationally, AP refers to assigning stable pitch-class labels or producing the corresponding tones without a reference. This differs from relative pitch, which estimates intervals from a heard standard and relies on short-term memory and comparison. The labelling component is central: AP requires mapping continuous frequency input onto discrete categories that remain stable across timbre and register.³

AP also serves as a framework for probing how biology and experience interact across development. Evidence from early musical training and tone-language exposure supports the idea of sensitive periods during which pitch categories are more easily acquired. In parallel, neuroimaging and intervention studies show that training reshapes plasticity.^{4,5} Despite decades of work, a core controversy remains: Is absolute pitch largely a genetic predisposition, or is it a skill learned through early environmental exposure? Converging lines of evidence include familial aggregation and genetic hints, on the one hand, and large prevalence differences tied to tone-language background and age of onset of musical training, on the other.^{6,7} This review weighs these strands to clarify how far each account can go and where they intersect.

■ Discussion

FoxP2 in Songbirds: The Zebra Finch:

When investigating complex biological processes such as vocal learning, researchers often turn to animal models that share similar auditory systems with humans. The zebra finch is an excellent example, serving as a powerful model organism for studying the genetics, neurobiology, and behavior of vocal communication. Such research has shown stark similarities between the songbird and human brain, particularly in the functionality of Area X in the zebra finch and the striatum in the human brain. Both structures serve an important role in the auditory system (Figure 1). Furthermore, the Pallium area (green) appears on the peripheral part of the brain in both organisms. Due to this homology, the zebra finch provides an accurate model that reflects certain functions of the human brain and can therefore be a favoured subject for study.

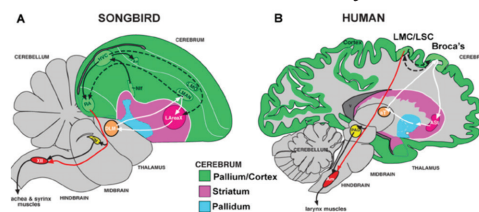


Figure 1: Auditory Pathways in Humans and Zebra Finches. This figure compares the auditory pathways of humans and zebra finches, illustrating key similarities in the organization of their vocal and auditory circuits. Panel A: zebra finch male brain section displaying connectivity of anterior (LMAN, area X) and posterior (HVC, RA) song pathways. Panel B: human brain section showing vocal pathway connectivity including the LMC/LSC and part of the anterior striatum (AS_t) that shows convergence with songbird RA and area X. Black arrows, connections and regions of the posterior vocal motor pathway; white arrows, connections and regions of the anterior vocal pathway; dashed arrows, connections between the two pathways.⁸

A High-Concurrency Design Based on FPGA for Aerospace Testing Systems

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ABSTRACT: Aerospace testing systems are crucial for the successful launch of spacecraft, responsible for conducting comprehensive health checks. As system devices grow increasingly complex, modern aerospace testing systems face high-concurrency challenges with over 2,000 channels. To address this, this paper proposes an FPGA (Field-Programmable Gate Array) architecture to replace the CPU (Central Processing Unit) for implementing the core task module—the real-time decision-making subsystem. First, a parallel logic architecture based on an FPGA is proposed. Leveraging experimental data, an adaptive mapping function between FPGA resources and the number of logic instances is fitted to address the matching issue between the quantity of parallel logic units and FPGA resources. Second, a hash mapping algorithm based on MurmurHash3 is designed to achieve the mapping between data channels and parallel logic units, thereby mitigating hash polarization and ensuring the balanced distribution of input signals across logic channels. Finally, a register rule writing algorithm based on modulus division is developed to guarantee the balanced allocation of decision rules in distributed registers. Additionally, a fast retrieval algorithm based on binary search is designed to enable efficient and rapid access to distributed registers. Test results show that the FPGA-based real-time decision-making system can automatically adapt to the FPGA resource structure, achieving a reduction in processing latency by more than 20 times and an increase in throughput by over 4 times compared to CPU systems, significantly enhancing the real-time processing capability of aerospace testing systems.

KEYWORDS: Aerospace Testing System, FPGA, Algorithms, Parallel Processing, Distributed Cache.

■ Introduction

The aerospace testing system^{1,2} is the ground-based core system in aerospace engineering, responsible for the integrated testing and launch control of carrier rockets and spacecraft. It spans the entire lifecycle of spacecraft, from design and manufacturing to launch, ensuring the safety and reliability of space missions through high-precision measurement and telemetry technologies. With advancements in modern aerospace technology, testing systems face significant high-concurrency challenges during mission execution. Modern aerospace missions require comprehensive real-time health sensing and monitoring of various aspects, including structural integrity, vibration, shock, thrust, combustion, leakage, power supply, equipment performance, and atmospheric conditions. As spacecraft systems become increasingly complex, real-time parallel processing of over 2,000 objects is required. The data generation rate from test objects can reach millions of sampling points per second, and the identification and anomaly detection of these signals must be completed within milliseconds. This poses significant performance challenges to the testing system.

The traditional testing system architecture, centered around the CPU, struggles to meet the requirements of high concurrency. The CPU is constructed based on the Single Instruction Stream Single Data Stream (SISD) paradigm,^{3,4} with limited Instruction-Level Parallelism (ILP), which severely hampers its ability to handle multiple tasks in parallel.^{5,6} Additionally, the "memory wall" phenomenon is particularly prominent in CPUs,^{7,8} as their shared bus architecture results in memory

access delays accounting for over 60% of the total processing time, significantly reducing the overall system efficiency. CPUs also exhibit notable limitations in real-time scheduling. Under a polling scheduling mechanism, the response time for 2000 channels can extend to several seconds, failing to meet the needs of testing subsystems for high-speed real-time data processing. To address these issues, we employ an FPGA to replace the CPU for real-time control and decision-making functions. Leveraging its exceptional parallel processing capabilities, an FPGA can execute multiple independent operations simultaneously, effectively meeting high concurrency demands. For instance, in spacecraft telemetry, tracking, and command (TT&C), an FPGA can simultaneously process orbital data for hundreds of targets, achieving a Query Per Second (QPS) in the millions, whereas traditional CPU architectures, constrained by core count and cache size, typically achieve a QPS only in the tens of thousands to hundreds of thousands.

This paper presents the design and implementation of a real-time decision-making function for a testing system based on an FPGA, which meets the requirements for real-time detection of a large volume of concurrent data. The main contributions are as follows:

1. Designed and implemented an FPGA-based real-time decision logic system.
2. Design and completion of a mapping algorithm for hardware resources and the quantity of parallel logic units.
3. Designed a mapping algorithm for signal channels and logic instances, employing the MurmurHash3 algorithm to ef-

A Visual Derivation Using a Signed Pascal's Triangle for Expansions of $\sin(n\theta)$ and $\cos(n\theta)$

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ABSTRACT: This paper presents a signed version of Pascal's triangle as a visual method to organize expansions of $\sin(n\theta)$ and $\cos(n\theta)$. Using these expansions, we compare $\sin(n\theta) + \cos(n\theta)$ to $(\sin\theta + \cos\theta)^n$. Although these identities can be derived from De Moivre's theorem, the main purpose is to provide a visual aid in understanding these expansions.

KEYWORDS: Mathematics, Pascal's Triangle, De Moivre's Theorem.

■ Introduction

In this paper, we investigated the expression $(\cos\theta + \sin\theta)^n$ and examined how it relates to $\cos(n\theta)$ and $\sin(n\theta)$. This expression is reminiscent of De Moivre's Theorem, which involves complex numbers through $(\cos\theta + i \cdot \sin\theta)^n = \cos(n\theta) + i \cdot \sin(n\theta)$. However, we focused on the real number version, which is without i , and uncover their identity.

It is already known that $\cos(n\theta)$ and $\sin(n\theta)$ can be written as polynomials using $\cos\theta$ and $\sin\theta$.^{1,2} These results usually arise from De Moivre's Theorem or recursive trigonometric formulas.^{1,2} But instead of focusing on algebraic derivations, we wanted to find a way to visually reflect those identities using combinatorial structure, specifically, through a variation of Pascal's Triangle.

Pascal's Triangle is a well-known structure in mathematics, where each row represents binomial coefficients arranged in a triangular format. While its applications in algebra are widely understood, its connection to trigonometry is not as well explored as algebra.^{3,4}

To do this, we developed a modified version of Pascal's Triangle where, letting the leftmost coefficient in each row be coefficient 1 and counting left to right, the coefficients with numbers equivalent to 0,3 (mod 4) in each row are assigned negative signs. For example, the third row is [1,2,-1], and the fourth row is [1,3,-3,-1].

				1						
			1	1						
		1	2	-1						
	1	3	-3	-1						
1	4	-6	-4	1						
1	5	-10	-10	5	1					
1	6	-15	-20	15	6	-1				
1	7	-21	-35	35	21	-7	-1			
1	8	-28	-56	70	56	-28	-8	1		
1	9	-36	-84	126	126	-84	-36	9	1	
1	10	-45	-120	210	252	-210	-120	45	10	-1

When we applied this modified triangle, in every row, a summation using the odd terms as coefficients summed to $\cos(n\theta)$, and a similar summation using the even terms summed to $\sin(n\theta)$:

$$\cos(n\theta) = p_{n-1,1}c^n + p_{n-1,3}c^{n-2}s^2 + p_{n-1,5}c^{n-4}s^4 + p_{n-1,7}c^{n-6}s^6 + \dots$$

$$\sin(n\theta) = p_{n-1,2}c^{n-1}s + p_{n-1,4}c^{n-3}s^3 + p_{n-1,6}c^{n-5}s^5 + p_{n-1,8}c^{n-7}s^7 + \dots$$

Where $c = \cos(\theta)$, $s = \sin(\theta)$, and $P_{a,b}$ denotes the b -th entry in the a -th row of the modified Pascal's triangle.

Note that while the topmost row of the triangle is the 0th row, the leftmost term of each row is the first term. This choice is to aid in intuitivity in reading summations, where a summation with n terms contains terms 1 through n rather than 0 through $n-1$.

By using two different versions of Pascal's Triangle, namely the standard triangle for expanding $(\cos\theta + \sin\theta)^n$ and the modified triangle for reconstructing $\cos\theta + \sin\theta$, we were able to establish an identity for the difference between the expressions.

Also, the modified triangle allowed us to generalize the trigonometric sums $\sum_{n=1}^k \cos(n\theta)$ and $\sum_{n=1}^k \sin(n\theta)$ in terms of $\cos\theta$ and $\sin\theta$, respectively.

■ Results

Theorem 1.

Letting the terms of the n -th row be $[p_{n,1}, p_{n,2}, p_{n,3}, \dots, p_{n,n+1}]$, $\cos(n\theta) = p_{n,1}\cos^n(\theta) + p_{n,3}\cos^{n-2}(\theta)\sin^2(\theta) + p_{n,5}\cos^{n-4}(\theta)\sin^4(\theta) + p_{n,7}\cos^{n-6}(\theta)\sin^6(\theta) \dots$ and $\sin(n\theta) = p_{n,2}\cos^{n-1}(\theta)\sin^1(\theta) + p_{n,4}\cos^{n-3}(\theta)\sin^3(\theta) + p_{n,6}\cos^{n-5}(\theta)\sin^5(\theta) + p_{n,8}\cos^{n-7}(\theta)\sin^7(\theta) \dots$

Proof.

We will derive formulas for $\cos(n\theta)$ and $\sin(n\theta)$ using De Moivre's Theorem, and then prove that the terms of the formulas are the same as row n of the modified Pascal's triangle.

First, recall De Moivre's Theorem:^{1,2}

De Moivre's Theorem states that $(\cos\theta + i \cdot \sin\theta)^n = \cos(n\theta) + i \cdot \sin(n\theta)$. Continuing to use the notation of $\cos\theta = c$ and $\sin\theta = s$, expanding the left-hand side gives:

$$\binom{n}{0}c^n + \binom{n}{1}c^{n-1}i^1s^1 + \binom{n}{2}c^{n-2}i^2s^2 + \binom{n}{3}c^{n-3}i^3s^3 + \dots = \cos(n\theta) + i \sin(n\theta).$$

Investigating the Effects of Controlled Cold Exposure on Brain Cell Integrity and Depression-Related Gene Expression

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ABSTRACT: Cold water therapy, which belongs to hydrotherapy, exposes patients to brief cold water treatments. It enhances immune function and metabolism while reducing pain from inflammatory conditions. This research examined how cold-water exposure affects both brain cell integrity and depression-related gene expression patterns in human subjects. The brain cell cultures were treated with DMEM culture media solution. Then, they were exposed to 4°C temperatures for 5, 15, 30, and 45 minutes under control conditions where untreated cells remained at 37 °C. Then, microscopic imaging was used to examine cell structure and survival rates. Then, the quantitative PCR was performed to measure CREB and BDNF gene expression levels. These results showed that cells maintained their morphology and viability after 45 minutes of cold exposure, yet cell size decreased proportionally to the duration of exposure. The mRNA levels of CREB and BDNF increased substantially (3–4-fold and 2–3-fold, respectively) in cells exposed to 45 minutes of cold treatment, indicating the activation of stress-protective signaling pathways. The research demonstrates that properly managed cold-water exposure can protect brain cells while altering depression-linked molecular markers, which supports its potential use as a depression treatment method.

KEYWORDS: Neuroscience, Cellular and Molecular Neuroscience, Cold Water Therapy, Brain Cell Integrity, Depression-Related Gene Expression.

■ Introduction

Cold water therapy is a form of hydrotherapy treatment that exposes patients to cold water for a short time.¹ It is widely regarded as physiologically beneficial for the human body as it enhances immune functions and metabolism and alleviates pain from inflammatory conditions such as muscle tension, asthma, and rheumatism.² To reduce muscle stiffness, mitigate post-exercise damage, and increase strength gains, athletes frequently treat themselves with cold water immersion therapy and cryotherapy.³ Accumulated days of cold showers also provide non-athletes with reductions in general sickness.⁴ Although cold water therapy provides a more exhaustive exposure to coldness, both cold showers and cold-water therapy allow the human body to experience the advantages of cold shock to the body.⁵

Cold water therapy contains effects beyond just its physical benefits. Many researchers have suggested cold water therapy as a potential treatment for depression, one of the most common yet fatal mental disorders in the world. Although the exact causes for depression are ambiguous, scientists predict that one major cause may be the lack of physiological stressors, such as changes in body temperature. Short-term exposure to coldness creates anti-depressive effects by activating the sympathetic nervous system. This mass release of noradrenaline, combined with the high density of cold receptors, sends many electrical impulses, diminishing the feeling of persistent sadness, emptiness, loneliness, fatigue, and futility.⁶ It is also uncovered that cold water therapy encourages the release of hormones and neurotransmitters related to the moderation process of stress, such as Dopamine, serotonin, cortisol, norepinephrine, and

β-endorphin. Cold water therapy also increases the interaction between the limbic structures of the brain. The medial and left rostral prefrontal cortices, left anterior insula, and anterior cingulate cortex begin to engage more frequently, resulting in an energetic and less distressed state of mind.⁷

Cell integrity is the unharmed or complete condition of a cell's structure and function. Cell injury occurs when cells are exposed to an overwhelming amount of external or internal stress to the point where they cannot sustain their lives without suffering damage. To a certain extent, cell injury is reversible; however, it eventually transitions to irreparable harm. Consistent or excessive cell injuries may lead to cell death.⁸ Countless studies have been conducted that address the effect of cold-water therapy on muscle cell integrity. Yet, few researchers are available to investigate the relationship between cold water therapy and brain cell integrity. Even amongst the small number of studies related to brain cell integrity, researchers disagree with each other. Many studies suggest that cold water therapy is beneficial overall. Treatment such as cold-water swimming rapidly increases endothelial progenitor cells (EPC) and angiogenesis in the blood circulation and hippocampus. This augmented generation of new vessels, usually active during cognitive development, improves recovery of cognitive functions previously damaged from brain trauma.⁹ On the contrary, many other studies have discovered that exposure to cold water can alter brain cells, decrease attention span, impair memory, and slow the response and decision-making speed.⁷

Current studies that investigate the effect of cold-water therapy on brain cell integrity and depression face numerous limitations despite the depth of each study. Many studies have

Advances In Reverse Osmosis and Nanofiltration Membrane Technologies for Sustainable Water Treatment and Desalination

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Mentor: Xue Ning

ABSTRACT: Worldwide water scarcity and contamination are increasing problems because of population growth, industrialization, and agriculture. Traditional water treatment processes are unable to remove the large quantities of emerging pollutants, and thus, there is a trend toward using membrane technology. In this paper, we review the development, performance, and applications of reverse osmosis (RO) and nanofiltration (NF) membranes. RO modules such as plate-and-frame, tubular, spiral-wound, and hollow fiber RO modules are compared in terms of their flux, salt rejection, energy requirements, and fouling resistance. The applications of RO and NF membranes for desalination and wastewater treatment are highlighted. NF operates between ultrafiltration and RO and has lower energy consumption than RO, and it can remove certain selective ions. NF can remove divalent ions and is effective at removing organic pollutants and heavy metals. Integrated cascading systems, Ultrafiltration (UF)-NF system or Powdered activated carbon (PAC)-NF system, were investigated, and the integrated system was found to improve NF performance by reducing fouling and extending the lifetime of the membrane. Case studies show that in two coastal villages in South China, membrane technology has provided the coastal villagers with a means of obtaining freshwater from seawater. We conclude that RO and NF have indispensable roles to play in the future of water management. However, NF coupled with appropriate pretreatment may provide more cost-effective and more environmentally sustainable solutions. Policy recommendations include investment in decentralized membrane systems fueled by renewable energy and training of local technicians to ensure long-term safe water supplies and sustainable resource use.

KEYWORDS: Engineering, Environmental Engineering, Water Resources Management, Recycling and Waste Management.

■ Introduction

With the vast development of industrial and agricultural demands and the booming global population, water source shortages and wastewater contaminants are no longer problems in a specific area but have become global problems.¹ We have an urgent need for sustainable water management, emphasizing technological solutions such as wastewater contaminants reuse, desalination, and improved water infrastructure. However, conventional water treatment methods cannot satisfy the emerging contaminant removal, so the advanced treatment technology, such as membrane filtration, has been developed.² In a case study in South China, many less-developed coastal fishing villages were found to be in short supply of fresh water. Due to their exceptional geographical advantages, they can filter seawater to obtain sufficient freshwater resources. This review aims to provide a comprehensive overview of reverse osmosis membranes and nanofiltration membranes technologies, discussing their recent development, key performance parameters, applications, and future perspectives. Local people and governments can use the information and suggestions provided by this paper to take some corresponding measures. Additionally, real-world case studies are included to illustrate practical applications.

■ Discussion

Reverse osmosis (RO) membrane:

Reverse osmosis (RO) is a membrane-based separation process used to remove dissolved salts, contaminants, and other impurities from water. It pushes water under a semi-permeable membrane under pressure and separates ions, molecules, and impurities in water by taking advantage of the selective permeability of specific membranes. Water is divided into two streams: one with low solubility and the other with high solubility.³ Low-solubility streams are called osmotic water or product water, while high-solubility streams are called concentrated water, brine, or waste liquid. Osmosis is a natural process that allows a highly concentrated solution to flow into a compartment with a weaker concentration of dissolved solids. If the concentration changes on either side of the membrane, the direction in which the water flows will not change⁴ (Figure 1).

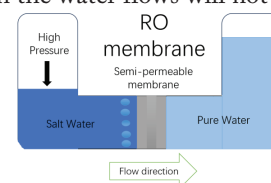


Figure 1: The process of the reverse osmosis membrane, which shows how the RO membrane works. In the schematic diagram, High pressure is applied to feed water, forcing pure water through a semi-permeable membrane while dissolved salts are retained. The blue dots represent sodium ions and chloride ions that are blocked by the membrane.

Forecasting and Preventing Child Labor in Artisanal Cobalt Mining in the DRC: Challenges, Data Gaps, and AI-Driven Recommendations

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ABSTRACT: The artisanal and small-scale mining (ASM) sector in the Democratic Republic of Congo (DRC) supplies 15–20% of global cobalt but relies on child labor in hazardous conditions. As cobalt is essential for batteries in electric vehicles and digital devices, addressing child labor in ASM operations represents a critical ethical and human rights challenge. Effective forecasting of such risks and associated mitigation strategies is vital to ensuring ethical and sustainable supply chains. At present, forecasting depends largely on human experts through NGO reports, government inspections, and corporate audits. This reliance introduces major limitations, including bias, data scarcity, inconsistency, and limited scalability. Consequently, high-risk regions are frequently overlooked, and interventions are delayed. This paper reviews these shortcomings and identifies ten structural drivers of child labor in cobalt ASM. It advocates a shift from reactive documentation to proactive prevention through the integration of data-driven forecasting methods. Proposed solutions include AI-supported analysis of satellite imagery, socio-economic indicators, governance data, and community reports, together with targeted interventions such as conditional cash transfers, mobile classrooms, blockchain traceability, and IoT-enabled monitoring. By improving forecasting accuracy and transparency, this work contributes to more effective child protection and the advancement of ethical, sustainable cobalt supply chains. This article presents a conceptual design framework rather than an empirically validated system. The proposed AI forecasting architecture is a structured model intended to guide future implementation and pilot testing, not a deployed or field-validated system.

KEYWORDS: Child Labor, Human Rights and Policy, Ethical Supply Chain, ASM Cobalt Mining, AI-Driven Forecasting.

■ Introduction

The Democratic Republic of Congo (DRC) depends on artisanal and small-scale mining (ASM) operations to supply most of the world's cobalt.¹ The essential component, cobalt, enables the operation of rechargeable batteries, which power electric vehicles, smartphones, and renewable energy systems. The DRC generates 70% of worldwide cobalt output, and ASM operations generate between 15% and 20% of this total amount.² The rapid growth of ASM operations in the DRC has created multiple severe problems for local communities because of increasing cobalt market demand from clean energy initiatives.

Thousands of children work in dangerous conditions at hazardous ASM sites located in the southern region of the DRC. The total number of cobalt miners reaches 255,000, yet 40,000 of them are under 18 years old, and some children start working at the age of six.³ The workforce of several districts contains between 30% and 70% of children under the age of 18.^{4,5} The use of child labor in cobalt mining has become a worldwide issue because "green" technology production relies on supply chains that contain child exploitation. Reports by the ILO and UNICEF confirm that tens of thousands of children working in ASM cobalt mines indirectly contribute to global electric vehicle and battery supply chains,^{6,7} underscoring the ethical risks tied to the clean energy transition. Estimates of child labor prevalence in cobalt ASM vary considerably across sources due to methodological differences, informal site mo-

bility, and limited access to remote regions. Reported figures should therefore be interpreted as ranges rather than precise counts. Media investigations, NGO reports, and institutional datasets often rely on sampling or extrapolation methods, and uncertainties remain significant. Where possible, this paper triangulates institutional, peer-reviewed, and advocacy datasets to reduce source-specific bias.

Major technology companies, including Apple, Google, Dell, Microsoft, and Tesla, face legal challenges and damage to their reputation because of child labor exposure in cobalt supply chains. The London Metal Exchange, through its sourcing policies and Cobalt for Development program, has launched industry reforms, yet these efforts have shown minimal success.⁸ The combination of poverty levels, dangerous workplace conditions, corrupt practices, and inadequate governance systems maintains the practice of child exploitation. These factors do not operate independently but instead reinforce one another across economic, institutional, and global supply chain dimensions. As shown in Figure 1, child labor in cobalt ASM emerges from a complex and interconnected network of drivers, including poverty, weak governance, unsafe working conditions, and rising global cobalt demand. The figure highlights that these factors do not operate independently, but reinforce one another in feedback loops, explaining why isolated policy or corporate interventions have struggled to produce sustained reductions in child labor.

Influence of Gut Microbiota on Risk and Prognosis of Hemorrhagic Stroke

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ABSTRACT: Hemorrhagic stroke is a highly fatal yet understudied cerebrovascular disorder. While genetic and proteomic factors have been widely studied as contributors to hemorrhagic stroke, recent research emphasizes the human gut microbiota as an important factor in the causation and progression of the disease. This literature review was conducted to highlight evidence surrounding microbiome composition's influence on hemorrhagic stroke risk and outcomes, addressing the knowledge gap on this topic. This review finds that Mendelian randomization, DNA sequencing, and case-control studies are the most frequently utilized methods in hemorrhagic stroke studies with a focus on the gut microbiome. These methods are used in collecting and interpreting the genomic and metabolomic data from various gut flora. In addition, these studies consistently revealed that specific pro-inflammatory bacteria taxa, such as Proteobacteria and Escherichia-Shigella, were elevated in stroke patients and influenced stroke outcome, as well as how metabolites such as trimethylamine N-oxide (TMAO) are linked to increased platelet reactivity, promoting vascular stress. The influence of gut microbiota on the risk and prognosis of hemorrhagic stroke suggests that certain gut bacteria may trigger inflammation and produce metabolites like TMAO that can stress blood vessels and increase the risk of clotting. Collectively, these findings suggest that the gut-brain connection may influence both the occurrence and prognosis of hemorrhagic stroke through metabolic and vascular pathways.

KEYWORDS: Medical and Health Sciences, Biology, Microbiome, Hemorrhagic Stroke, Gut-Brain Connection.

■ Introduction

With regard to finding relationships between the microbiome and cerebrovascular disease, there is a lack of unification among the various findings and concepts illustrated by current research. Additionally, given that hemorrhagic stroke is a comparatively rare condition, research tends to focus on the more common ischemic stroke variety. This review aims to unify the findings of current research surrounding the microbiome's effects on hemorrhagic stroke and increase awareness of this condition in general.

Not to be conflated with ischemic stroke, hemorrhagic stroke is a medical emergency identified by a ruptured blood vessel in the brain. Within the category of hemorrhagic stroke, there are intracerebral hemorrhage (ICH) and subarachnoid hemorrhage (SAH), which differ based on the locality of the bleeding site.¹ By comparison to its ischemic counterpart, hemorrhagic stroke typically entails a higher mortality rate and a more adverse prognosis, while simultaneously constituting a smaller percentage of the total worldwide documented cases of stroke. Indeed, in 2021, ICH constituted 28.8% (28.3 to 28.8) of incident strokes globally, and SAH constituted 5.8% (5.7 to 6.0) of incident strokes globally.² The mortality rate for ICH is 42 (38 to 46) per 100,000 cases per year, and the mortality rate for SAH is 4 (4 to 5) per 100,000 cases per year.² On account of its high mortality rate and comparative rarity, research on not only its effects but also its causality must be explored. Among contemporary research surrounding the causality of ICH and SAH, there is a primary focus on proteomic and genetic biomarkers, namely glial fibrillary acid protein (GFAP),

anti-N-methyl-D-aspartate (anti-NMDA) neuroreceptor antibodies, D-dimers, and RNA expression, to name a few.³ Conversely, there is a relative paucity of research honing in on the specific impact on ICH and SAH of an unlikely source that all humans share: the gut microbiota.

While seemingly extraneous to ruptured blood vessels within the skull, the bacteria present in the human gut may play a role in vascular inflammation and blood pressure, as well as possess a connection to the central nervous system through the microbiota-gut-brain axis. This literature review highlights and discusses the methods used in collecting and analyzing the data, as well as contextualizes and provides an overview of the literature related to the effect of human gut microbiota on the brain. These findings could help illustrate the factors that contribute to rare hemorrhagic strokes as well as provide commentary on how to conduct further research based on analysis of the most effective methods.

■ Methodology

This literature review aims to highlight the comparatively under-researched microbiotic aspect of hemorrhagic stroke using related peer-reviewed papers and honing in on the fundamental results that stem from them. The studies being reviewed in this paper were sourced through online databases PubMed and Google Scholar. Searches were conducted using the following Boolean keyword combinations: "gut microbiota" or "intestinal flora" or "microbiome," and "hemorrhagic stroke" or "intracerebral hemorrhage" or "subarachnoid hemorrhage" or "cerebrovascular rupture." Search filters were applied to include

Nanoformulated Treatments for Iron Deficiency Anemia

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ABSTRACT: Iron deficiency anemia is one of the most common nutritional disorders, impacting more than 30% of the world. IDA is extremely prevalent, especially in third-world countries. Some leading causes of IDA are poor diet intake and heavy blood loss. Many conventional medications include oral ferrous sulfate, ferrous gluconate, and intravenous injections. However, IDA still persists as a leading deficiency. This is due to the severe gastrointestinal side effects, which impact patient compliance. New emerging nanoformulations can mitigate side effects while maintaining or even increasing absorption. In this literature review, this paper examines numerous studies on conventional therapies and nanoformulations. Comparing dosages, efficiency, and general reception, it was found that nanoformulations are superior to traditional medications. Specifically, nanoferric pyrophosphate was found to be superior to other nanoformulations. This is beneficial for IDA in both first and third-world countries. However, more clinical research needs to be done in order to better understand the full range of nanoformulations on humans.

KEYWORDS: Biomedical and Health Sciences, Nanomaterials, Iron Oxide Nanoparticles, Iron Deficiency Anemia, Iron Supplementation.

■ Introduction

Iron deficiency anemia (IDA) is one of the most common blood conditions that impacts one's red blood cells. According to the World Health Organization (WHO), IDA is one of the most common dietary deficiencies in the world, with over 30% of the population being affected by this condition.¹ In the United States, around one in four adults suffers from inadequate iron absorption or intake.² Without enough iron, the human body cannot produce sufficient hemoglobin. Hemoglobin is the protein contained in red blood cells that is responsible for the delivery of oxygen to the tissues.³ Symptoms associated with IDA include, but are not limited to, excessive tiredness, dizziness, fatigue, lethargy, hair loss, and lightheadedness.^{4,5} Iron deficiency anemia has shown outcomes of poor pregnancy outcomes, poor motor and mental performance in children, and low work productivity in adults.⁵ On society as a whole, this impacts several factors, including significant economic losses, reduced quality of life, and impaired human development. Impaired human development is one of the most critical impacts of IDA. Due to the cognitive losses, the work capacity of adults also significantly decreased.⁶

In order to treat IDA, traditional medication includes oral iron supplements and intravenous iron injections.⁵ However, these traditional routes are associated with major gastrointestinal (GI) side effects such as nausea, constipation, and diarrhea, which impact up to 50% of patient compliance.⁵ New technologies, such as nanoformulated technologies, aim to mitigate risks. Nanoscience is an emerging field in science with many new opportunities for applications, especially in medicine. It can be defined as the science involving the design of materials on a nanometer scale, or one billionth of a meter. Nanoformulated iron is hypothesized to be a better approach compared to conventional iron due to its larger surface area, which enhances absorption.⁷

Conventional oral iron supplements, like ferrous sulfate, are effective and commonly used in increasing iron levels. However, the absorption of iron is dependent on food intake and dosage. While an empty stomach is optimal for iron absorption, many side effects are present: gastrointestinal side effects such as nausea, constipation, and diarrhea are common.⁵ In comparison, nanoformulated iron supplements such as liposomal iron, sucrosomial iron, and iron oxide nanoparticles, when used properly, address traditional concerns. These formulations enhance iron bioavailability by increasing its solubility and using alternatives.⁵

There are many conventional medications meant to treat IDA. Yet, IDA remains the largest nutritional deficiency in the world. Nanotechnology is an emerging field that can reduce the significant number of patients with IDA. The close evaluation between nanoformulated iron supplements and conventional therapies is crucial for advancing both science and public health sectors. Addressing this topic allows for new mechanisms in iron absorption. Additionally, it allows physicians a broader scale of pharmaceuticals to address iron deficiency anemia, reduce the side effects, especially in areas with populations with histories of low immunity or tolerance, which has led to poor adherence. Widespread use of solutions in high-risk groups like young children or pregnant women can reshape policy decisions regarding iron supplementation protocols in resource-poor areas. This bridges the gap in nutritional health worldwide, making therapies more accessible and acceptable worldwide.

■ Methodology

The primary aim of this study was to examine the recent advancements in nanoformulations in IDA. The objective of this literature review was to explore how nanoformulated iron delivery systems enhance iron bioavailability and absorption

Policy towards a Renewable World

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ABSTRACT: As concerns about the environmental impacts of fossil fuels increase, there is a strong push to transition to renewable energy sources, which are crucial for today's and future societies. Policy plays a vital role in promoting the development of renewable energy. In this context, we systematically analyze the policies and their impacts on renewable energy development in the United States and China, with a focus on wind and solar energy. Perspectives on future policymaking are discussed in terms of global cooperation, technological innovation, resource allocation, information exchange, and artificial intelligence. We hope this analysis will aid in developing more efficient strategies to promote the transition to a cleaner, more renewable world.

KEYWORDS: Climate Change, Renewable Energy Policies, Environmental Protection, Greenhouse Gases, Carbon Emissions, Wind Energy, Solar Energy.

■ Introduction

Our planet has been heavily polluted by large amounts of greenhouse gas (GHG) emissions, primarily CO₂, produced by the widespread use of fossil fuels that began in the 19th century. From 24,500 Mt in 1970 to 53,786 Mt in 2020, global GHG emissions have increased by more than 100% (Figure 1).¹ In particular, emissions have increased more rapidly due to global economic growth. This has led to severe environmental pollution and climate change, thereby presenting a major threat to our living environment. The temperature has increased by 1 °C compared to the pre-industrial era, leading to more extreme weather conditions.² In recent years, there have been several air pollution events that have killed thousands of people, such as the Great London Smog of 1952, the Eastern China Smog in 2013, and the severe smog in Delhi, India.³⁻⁵ People have been more concerned with GHG emissions and have been taking action to change and stop the increasing trend of GHG emissions. Although GHG emissions are still increasing in developing countries, including China, India, Brazil, Russia, and others, they have gradually decreased in developed countries since the 21st century.¹

With the agreement that protecting the environment is a common task for all people globally, action has begun. The Paris Agreement, a global international treaty on climate change, was established in 2015 and has been adopted by 196 parties.⁶ It aims to hold "the increase in the global average temperature to well below 2 °C above pre-industrial levels" and to pursue efforts "to limit the temperature increase to 1.5 °C above pre-industrial levels." Many countries have committed to reducing greenhouse gas (GHG) emissions and setting target goals for achieving net-zero emissions, which involves balancing all types of greenhouse gases, not just CO₂. For instance, most countries aim to reach net-zero emissions by 2050, including the United States, Japan, the EU27, Brazil, and Russia. Meanwhile, China has pledged to peak its CO₂ emissions before 2030 and achieve carbon neutrality, balancing

CO₂ emissions with an equivalent amount removed from the atmosphere, by 2060 (Figure 1). The essential strategy is transferring energy resources from non-renewable fossil fuels to renewable energies, such as wind, solar energy, and hydropower. This transition requires substantial societal reform and designated action from all parties to reduce and eventually eliminate the use of non-renewable fossil fuels.

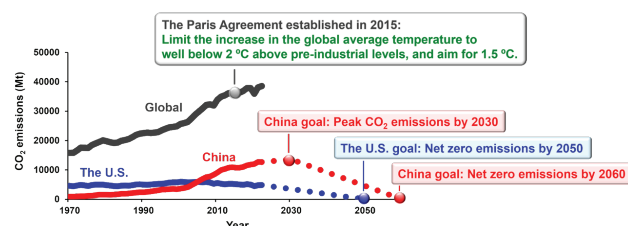


Figure 1: CO₂ emissions of global, China, and the U.S., and the targeted goals of China and the U.S. (Data sources: International Energy Agency). The Paris Agreement, a global international treaty on climate change, was established in 2015, and the U.S. and China have pledged to reduce GHG emissions and set target goals to reach net-zero emissions.

To reduce carbon emissions and promote the use of renewable energy, the United States and China, the two largest economies in the world, have implemented a series of policies to provide strong support since the 21st century. China has enacted numerous laws, regulations, and strategies to develop renewable energy technologies, achieving exceptional outcomes, particularly in the wind, solar, and hydropower sectors. The United States is also working to advance renewable energies. Federal and state governments have enacted various acts, regulations, and strategies to support the transition to renewable energy.

Here, we analyze the influence of policies in the United States and China on the development of renewable energy, focusing on wind and solar power as representative examples due to their rapid growth and renewability. We hope this can help in developing more efficient strategies to promote the transition to a more renewable and cleaner world. Besides domestic policies, the implementation of policies and the development