MONTANA STATE UNIVERSITY STUDENT RESEARCH CELEBRATION WINTER 2022

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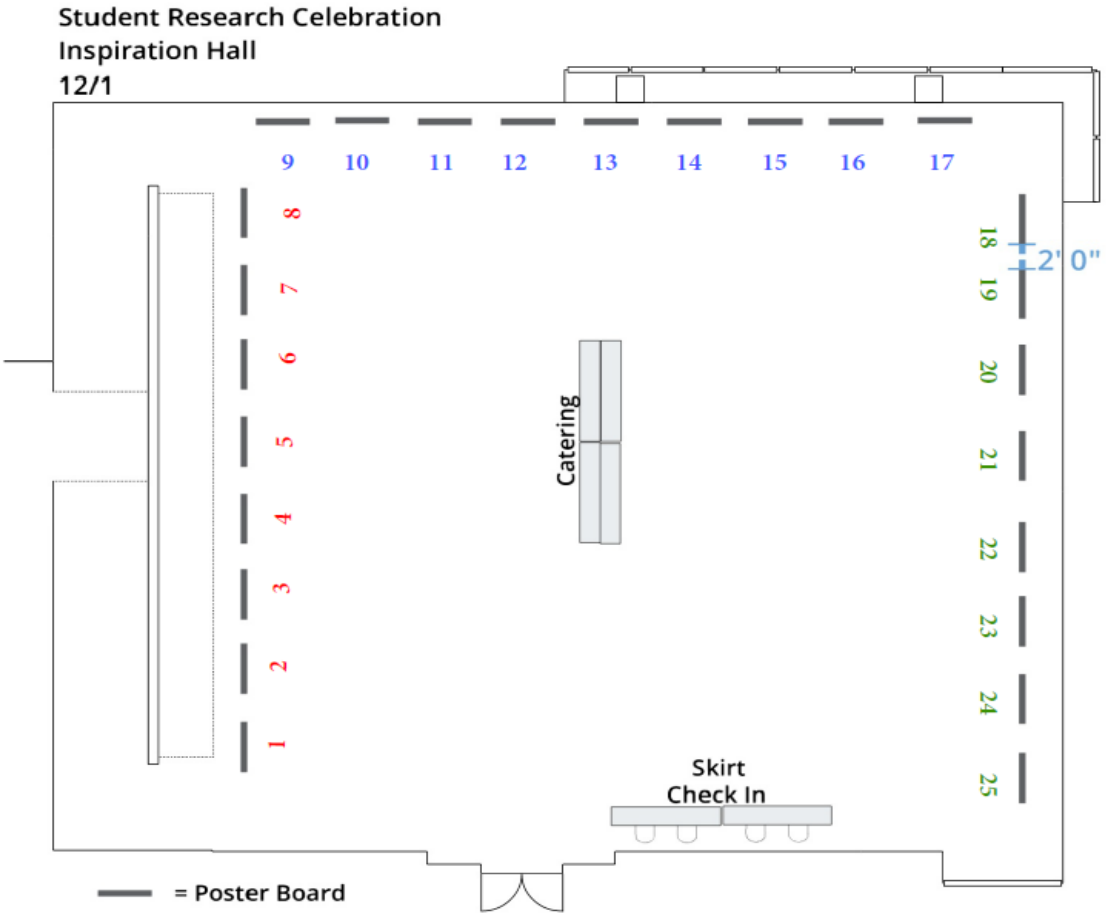

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STUDENT PRESENTATION ABSTRACTS

Using MicroCT Data to Reveal Anatomical Details in a New Crocodylomorph Taxon from the Blackleaf Formation (Albian-Cenomanian) of Southwest Montana

Harrison Allen, Earth Sciences
Mentor(s): David Varricchio, Earth Sciences

The mid-Cretaceous Blackleaf Formation (Albian-Cenomanian) represents a relatively poorly understood interval of geologic time within southwest Montana with regard to vertebrate paleoecology. Only two distinct vertebrate taxa have been described from the Blackleaf Formation: Oryctodromeus cubicularis and Gyptops sp. Fieldwork completed in 2021 near Lima, MT uncovered material of a potential new crocodylomorph taxon from the Vaughn Member of the Blackleaf Formation. This small specimen preserves much of the skull with closed lower jaws in addition to appendicular and axial postcranial elements. Its small size (~50 mm long skull), overlapping bones, and adhering matrix made it a poor candidate for physical preparation. MicroCT data was used to create a segmentation 3D model of the skull and other elements. Due to the nature of the similar densities of the rock matrix and fossil material, the segmentations so far generated are not final, and further scanning is required. The specimen appears to share similarities with other known small neosuchian Paralligatorids, such as Wannchampsus kirpachi and the largely undescribed 'Glen Rose Form.' Shared characteristics include a dorsal midline ridge spanning across the frontals and parietals, choanae with anterior contact with the palatines, and an enlarged third maxillary tooth.

Acknowledgments: USP - Undergraduate Scholars Program

The Effects of Temperature on Salmonfly Body Size, Dispersal & Fecundity

Niah Brass, Land Resources & Environmental Sciences
Mentor(s): Lindsey Albertson, Ecology; Alzada Roche, Ecology

It was hypothesized that salmonflies (Pteronarcys californica) at warmer sites will emerge earlier and will be smaller in body size at emergence and thus carry fewer eggs. Our goal was to collect a sufficient amount of data in order to test this hypothesis and see if increases in water temperature have a relationship with fecundity and dispersal of the salmonfly on the Madison and Gallatin Rivers. Measurements of randomly sampled salmonfly wing lengths were used as a proxy for the salmonflies ability to disperse. Prior research has established a linear relationship between mean May temperature and date of emergence (Anderson et al. 2019). Early results from the data show a negative relationship between emergence date and wing length. Therefore, based on the data, the salmonflies that emerged earlier seemed to have larger average wing lengths, which is the opposite of the trend we expected to see. Similarly, body size seems to decline at the later emergence dates. Salmonflies at the site below Hebgen Reservoir, which emerged the latest, seem to have smaller body sizes then the site at Jack Smith, which emerged earlier. Based on the current data, we have not detected a pattern with fecundity at different sites.

Acknowledgments: USP - Undergraduate Scholars Program

The MSU Design-Build Master's Thesis Tiny Home Proposal

Christopher Brizzolara

, Architecture

Let's provide a way to let MSU Architecture students to build their own home, and start their careers with a real-life design-build experience in Bozeman. They will be the designers, project managers, and builders, plus upon completion, they would have a huge economic advantage, and an asset that increases in value over time, all while obtaining a master's degree in the process.

Gut Microbiome Residency of Bacteroides Species

Zea Cain, Microbiology & Cell Biology
Mentor(s): Seth Walk, Microbiology & Immunology

The goal of this research is to evaluate the population dynamics of Bacteroides in the human gut microbiome and discover how individual asexually reproducing clones within this population change over time. This project uses the same samples as previous research done in the Walk Lab, research that discovered Escherichia coli is the most resident and abundant species of Enterobacteriaceae in the human gut. This project is testing the hypothesis that Bacteroides species evolve differently in the human gut compared to E. coli, perhaps becoming less resident and more transient. The topic is especially important to public health as the majority of studies regarding Bacteroides pertain to antibiotic resistance, pathogenesis, nosocomial infection, and water quality assessment. Longitudinal and ecological studies related to naturally occurring, nonpathogenic Bacteroides are uncommon, so there is very little information overall about how members of this genus evolve. Initial results have indicated that Bacteroides have a wide range of how long they reside in the gut, varying greatly between different species. It has also been implied that some Bacteroides clones may exist in the gut of different patients, which is unique in that bacterial clones have been found to be specific and individualized to their environment.

Acknowledgments: USP - Undergraduate Scholars Program

A Comparison of Occlusal Surface Complexity in the Dental Batteries of Hadrosaurids

Heath Caldwell, Earth Sciences
Mentor(s): David Varricchio, Earth Sciences

Among Dinosauria, the hadrosaurid dentition is notable for both its histologic complexity and elaborate arrangement of individual teeth. Variations in the dental occlusal surface as well as skull biomechanics among hadrosaurid taxa have been used to make inferences about the differing dietary ecologies within this clade. Orientation Patch Count (OPC) is a quantitative measurement of the surface complexity of an object and has been found to correlate strongly with diet when applied to the dentitions of various vertebrates. In this study, OPC was applied to dental occlusal surface scans of the right dentary of the hadrosaurid Hypacrosaurus stebingeri. Comparisons of different sections of the occlusal surface show that optimal patch count values decrease mesially for this taxon. Visual examination of the occlusal surface shows that the mesial-most teeth have a more planar occlusal surface, while those of the distal teeth are more concave. The mesiodistal variations in OPC values lend support to the hypothesis that hadrosaurid teeth were not uniformly worn along the length of the occlusal surface. Possibly, the distal end of the occlusal surface was more involved in plant processing than the mesial end. Although more specimens are needed to test this hypothesis, these findings highlight the importance of considering variations in occlusal morphology when reconstructing hadrosaurid skull biomechanics. Additionally, comparison of OPC values among different hadrosaurids offers an avenue for exploring the dietary niches within the group.

Acknowledgments: USP - Undergraduate Scholars Program

HRV Biofeedback Training and Attention Control

Emma Christopher, Psychology; Audrey Hood, Psychology
Mentor(s): Keith Hutchison, Psychology; Audrey Hood, Psychology

The intention of this research is to investigate the relationship between attentional control and heart rate variability (HRV). Attentional control is the ability to maintain focus on a task in the face of distraction and HRV reflects the acceleration and deceleration of heart rate in response to both internal and external triggers. Working memory capacity (WMC) is measured as well due to its ability to predict real-life performance. A WMC baseline is gathered through completing two computer tasks - the Automated Operation Span Task and the Symmetry Span. This study focuses on the significance the initial biofeedback training period has on attentional control. Participants were randomly assigned into two separate groups - one group performed biofeedback training (the experimental group) and the other group completed word search exercises (the active control group). BioNomadix wireless physiological electrocardiogram sensors were used in this study to compile physiological data as well InnerBalance sensors. These sensors use pulse data to gather information about the participant and use real-time feedback to help participants change their heart rate rhythm patterns to reach physiological coherence. Changes in attentional control were measured before and after the intervention. The improvements in attentional control abilities were examined as well after the intervention for those lower in WMC. The research found that HRV biofeedback improves attentional control performance and that it improves attentional control performance more for those lower in WMC. These results are significant as it gives insight into a possible intervention to improve task performance, especially for those with lower WMC.

Acknowledgments: USP - Undergraduate Scholars Program

The potential for guided neurite outgrowth in response to nanomagnetic forces in synergy with Aripiprazole

Madeline Conrad, Chemistry & Biochemistry; Mackenna Landis
Mentor(s): Anja Kunze, Electrical & Computer Engineering

Neuronal circuits rely on consistent network connections, to communicate effectively. In native brain tissue these network connections are established through synergistic mixture of biochemical and mechanical signals that aid in neurite growth and orientation. Mental disorders such as schizophrenia often go along with a decreased number of neurite branches at the tissue-level causing a reduction in network connections. In previous studies, antipsychotic drugs such as aripiprazole and olanzapine have been shown to increase the number of neurite branches; however, antipsychotics alone have not been shown to orient the neurites. Hence, we focus on a neurotherapeutic approach to accomplish growth and orientation that combines mechanical force actuation and growth stimulation. Previous research in the Kunze Lab has demonstrated neurite orientation based on nanomagnetic forces (NMF) following a magnetic ascent. Here, the combination of antipsychotic drugs and NMF effects were studied on PC12 cell neurite growth patterns. We found that extracted neurite traces had preferred neurite growth directions within the ascent of the magnetic field and grew about 17% longer than in the control group. These findings indicate that NMFs, in synergy with antipsychotic drugs, may help orient and guide neurites for targeted cell therapeutics and tissue engineering.

Acknowledgments: Undergraduate Scholars Program & INBRE - IDeA Network for Biomedical Research Excellence

Automated Subsampling of Long-Term Bioreactor Effluent with Microfluidic Demultiplexing

William Culhane, Chemical & Biological Engineering; Humberto Sanchez, Chemical & Biological Engineering
Mentor(s): Connie Chang, Chemical & Biological Engineering

The ability to control fluid flow and prepare samples from a bioreactor would enable running long-term perfusion experiments without requiring repetitive manual sampling at specific timepoints. One way to achieve this is through the development of portable and autonomous devices. For milli-fluidic bioreactors that operate on miniaturized scales, we aimed to design a device to route flow from an inlet channel to a specific outlet channel based on the status of a pneumatic input signal (a demultiplexer). To create the demultiplexer, device masks for each layer were designed using CAD software and master molds were fabricated using photolithography. Device layers were made from polydimethylsiloxane (PDMS) using soft lithography and bonded together. The demultiplexer pneumatic control lines were controlled by solenoid valves upstream. A solenoid driver circuit was designed and assembled to control the demultiplexer selected output, and a microcontroller was connected to the circuit to demonstrate the ability to reconfigure sampling intervals. Testing of this device and driver circuit will assess device response time and pressure requirements for valve actuation. Overall, this work will enable portable and autonomous sampling of a bioreactor.

Acknowledgments: USP - Undergraduate Scholars Program

Root Microbiome Assembly Under Drought Stress

Lydia Diehl, Ecology
Mentor(s): Brent Peyton, Chemical & Biological Engineering; Hannah Goemann, Center for Biofilm Engineering

Plants respond to drought in many ways. For example, research shows that diverse root microbiomes increase plant survival in drought conditions by supporting nutrient uptake and increasing growth (Trivedi et al. 2020). Under stressful conditions plants can exude carbon compounds into the soil to support microbial activity. This project focuses on blue gramma (Bouteloua gracilis) which is a warm-season grass that can store large amounts of its carbon in its roots. The goal of this project is to study the carbon allocation and root microbiome of blue gramma under drought. Soil was collected from four geographic locations in Montana to grow blue gramma in greenhouses. Plants were randomly selected to be exposed to drought or non-drought conditions. Stable isotope labeling was performed and plant and soil samples were collected. Bacterial DNA was extracted from the soil samples and amplified with a universal 16s rRNA gene marker then sequenced. Operational taxonomic units were classified and analyzed to compare microbiome assemblies of different plants. DNA was also extracted from the four different soils and was sequenced and analyzed. Results of these analyses show that microbiome assemblies varied at these locations along a precipitation gradient. This suggests that historic precipitation regimes could affect how plant microbiomes assemble under changing climate conditions. Further research could determine how carbon allocation to roots affects microbiome structure under drought and non-drought conditions.

Acknowledgments: USP - Undergraduate Scholars Program

Characterization of the role of Complexin isoforms in presynaptic structure and function at Drosophila neuromuscular junctions

Payton Dupuis, Chemical & Biological Engineering; Elizabeth Brija, MIT Brain and Cognitive Sciences; Suresh Jetti, MIT Brain and Cognitive Sciences; Troy Littleton, MIT Brain and Cognitive Science
Mentor(s): Troy Littleton, Chemical & Biological Engineering

Communication between neurons is critical for brain function and for supporting learning and memory. The primary mechanism for neuronal communication requires calcium entry into the presynaptic terminal, triggering synaptic vesicle fusion with the plasma membrane via the SNARE complex and subsequent release of neurotransmitters. Complexin (Cpx) is a small, α-helical protein that regulates SNARE complex assembly to control both spontaneous and evoked neurotransmitter release. The Drosophila neuromuscular junction (NMJ) is an excellent model synapse to study synaptic transmission. Drosophila express a single Complexin gene (DmCpx) that encodes two isoforms, Cpx7A and Cpx7B, that differ at the C-terminus. Past research (Buhl et al., 2013) has shown that Cpx7A is the more abundant splice variant and better at rescuing enhanced spontaneous release observed in Cpx mutants. Using CRISPR techniques, Drosophila were modified to have early stop codons that disrupt either Cpx7A or Cpx7B, allowing analysis of endogenous isoform-specific function and expression patterns. Dissection and immunostaining of 3rd instar larvae lacking each isoform revealed Cpx7A is indeed the more abundant isoform compared to Cpx7B. Additionally, isoform-specific deletion of Cpx affected synaptic growth, as demonstrated by an increase in active zone number in mutant animals. Together, these findings suggest the Cpx7A isoform is the primary regulator of neurotransmission and synaptic growth at neuromuscular junctions, with a more minor role for Cpx7B. Future work will determine how Cpx function and expression is regulated at NMJs, and how the distinct Cpx isoforms may participate in synaptic transmission and plasticity.

Acknowledgments: McNair Scholars Program

Gender and Linguistic Structures of Crowdfunding

Hannah Easterday, JJCBE Center for Entrepreneurship
Mentor(s): Agnieszka Kwapisz, JJCBE Center for Entrepreneurship

Crowdfunding is one of the most accessible ways of raising money for a project, with no need to rely on traditional models of financing. This study focuses on a new type of crowdfunding –subscription-based crowdfunding. We use Patreon which lets content creators run a subscription service. The creator economy is a growing industry estimated to be worth more than $100 billion. We focus on podcast creators. We found that 54% of podcasts have less than 10 patrons and 86% have less than 100 patrons. We analyzed the linguistic characteristic of the campaigns' text descriptions using LIWC-2022 software. The results from the estimation of the log of earnings per month and the log of the number of patrons revealed that shorter descriptions and longer-running podcasts were more successful in these two measures. Higher authentic and emotional tone had lower total earnings and number of patrons. Campaigns' descriptions that used more "you" pronouns had significantly higher earnings and patrons but the opposite was true for "I" pronouns. Using data for top podcasts, we found that female podcasters had significantly lower earnings and number of patrons compared to male podcasters and mixed-gender teams (as we see in traditional ways to raise money). Female podcasters used significantly more "I" pronouns, more emotional tone (positive, negative, anxiety, sadness), prosocial words that signal helping or caring about others, and more exclamation points and "netspeak" (e.g., "lol", "4ever"). We are still in the process of analyzing ways female podcasters can use to increase their campaigns' success.

Acknowledgments: USP - Undergraduate Scholars Program

Validation of a portable treadmill designed to perform perturbation-based training to improve balance recovery in older adults

Robert Griffin, Health & Human Development; Justin Whiten, Health and Human Development; David Graham, Health & Human Development; Dawn Tarabochia, Health and Human Development
Mentor(s): David Graham, Health & Human Development; Justin Whitten, Health and Human Development

Perturbation-based training (PBT) is a reactive balance training method that causes a trip like event requiring a rapid step response to regain balance. There are numerous examples in the literature demonstrating the effectiveness of PBT but the need to use an expensive treadmill in a scientific laboratory limits the general applicability of PBT as a community-based intervention. A solution to this problem was the design and construction of a custom treadmill that was low cost, portable and capable of inducing rapid perturbations to balance. The purpose of this investigation was to validate the effectiveness of a custom designed PBT-treadmill. Four younger adult participants who were part of the research team completed a single-session of PBT on a custom treadmill designed at and built at Montana State University. Participants experienced a series of perturbations of varied magnitude which were both of equivalent to the perturbation intensity reported in previous studies and those used within the research groups current studies. The influence of the perturbations was measured using and inertial motion capture system. The primary outcome measure was the angle made between the lower body and the trunk, known as the peak trunk flexion angle, during the first step of the balance recovery response. Peak trunk flexion angles induced in the current study closely matched those from previous studies. We conclude that the custom designed treadmill is capable of reliably and repeatedly producing the required intensity of perturbations associated with improving reactive balance ability in older adults.

An attempt to streamline the Music Education degree at Montana State

Nathan Hallauer, Music
Mentor(s): Greg Young, Music

This project explores areas of duplication or superfluous coursework in the BME degree at Montana State University (MSU), to address the current teacher shortage. Questions include what is most beneficial, and how to streamline the curriculum to enhance graduation rates while ensuring future music educator preparedness. I plan to interview music faculty who come from different curricula, and survey students about options for a more specific focus in their degree, such as secondary, instrumental, elementary, etc. Sharing the results of this study with administrators and the music curriculum committee at MSU could have a positive effect on future BME students and their paths toward this rewarding career.

A study of Orodromeus taphonomy at Egg Mountain, part of the Upper Cretaceous Two Medicine Formation near Choteau, MT

Zakaria Hannebaum, Earth Sciences
Mentor(s): David Varricchio, Earth Sciences

Orodromeus makelai was a small thescelosaurid dinosaur known from the Upper Cretaceous Two Medicine Formation (TMF) of Montana, and notably from the Egg Mountain (EM) quarry. Most dinosaur fossils at EM consist of preserved eggs and clutches mostly of the troodontid Troodon formosus, whereas Orodromeus is represented entirely by skeletal material. This study seeks to determine the unique taphonomic factors driving the preservation of Orodromeus material at EM by exploring three hypotheses: (1) Orodromeus was fossorial, like the closely related Oryctodromeus cubicularis, and burrowing facilitates its preservation; (2) the abundance of fossils reflects an Orodromeus breeding ground, and (3) Orodromeus remains represent individuals preyed upon and gathered by Troodon.

New Orodromeus fossils collected from EM between 2010 and 2016 have helped shed light on the taphonomic processes affecting Orodromeus with potential insights into parental care strategies. Preparation of a plaster field jacket designated "Jacket A" has revealed an articulated juvenile Orodromeus skeleton with taphonomic characteristics first observed in Oryctodromeus. These observations show burrows are likely providing a sheltered environment for Orodromeus carcasses to decay free from detrimental environmental and predatory factors leading to their exceptional preservation at EM.

Analysis of the Orodromeus death assemblages at EM and the TMF revealed EM lacked perinate, young juvenile, and adult aged animals. This analysis also showed Orodromeus exhibited delayed attrition compared to other dinosaurs with peak attrition occurring in potentially 2 year old animals. Therefore, perhaps peak attrition correlates with the age Orodromeus became independent of direct parental.

Acknowledgments: USP - Undergraduate Scholars Program

Analyzing the Benefits and Challenges of Performing Outdoors vs. Indoors

Faith Himmel, Music
Mentor(s): Greg Young, Music

Regarding musicians performing outdoors, many people initially think of parades and music festivals. However, there are many other opportunities for musical performance in an outdoor setting. This study contains information on the different performance applications of music outdoors, including marching band and concert ensembles, along with providing the best and worst aspects of performing outdoors as an ensemble. Through a survey and interviews, these aspects will also be compared to those of an indoor performance, including the pitch variation and ensemble attitude. There are many challenges that can come with performing outdoors, especially in a concert ensemble setting. The research question centers on whether benefits found in this project outweigh the challenges, and whether performing outdoors is a worthwhile experience for some ensembles and some performers.

Acknowledgments: USP - Undergraduate Scholars Program

Cumulative Risk from Drinking Water Contaminants in Home Wells, Gallatin, and Madison Watersheds MT

Emory Hoelscher-Hull, Microbiology & Cell Biology
Mentor(s): Mari Eggers, Microbiology & Immunology

Access to safe drinking water is an issue most Americans associate solely with developing counties, however, many rural Americans rely on private drinking water sources that may not be tested or treated for contaminants, and thus pose a risk to human health. Unlike public water supplies, private drinking water is not regulated by the Environmental Protection Agency. Instead, testing and treatment of well water is left up to well owners who may not be aware of potential contaminants present in their water or the health effects associated with these contaminants. Education of well owners is an important step in protecting the health of rural Montanans.

The objectives of this research project included: (1) calculating the cumulative risk posed by lifetime consumption of home well water for residents living within the Gallatin and Madison watersheds in Montana using available data from the Ground Water Information Center, and (2) conducting a literature review of existing well water contaminant and risk communication best practices and formatting a communication guide. Future directions for this project include using this information to inform the creation of educational materials for public health officials and residents of Gallatin and Madison counties. These materials will emphasize the importance of well water testing and direct well owners to MSU's

extension program, Well Educated for testing and interpretation of testing results. These materials will also communicate a high-level idea of what contaminants are likely to be present in residents' well water.

Acknowledgments: USP - Undergraduate Scholars Program

The Effect of Religious Backgrounds on Musicians' Career Paths

Rachel Huenink, Music
Mentor(s): Gregory Young, Music

Music is a significant aspect of worship for many religious experiences. As such, it can be seen as an influence on a person's love of music. Does the exposure to music in religious contexts, such as listening to hymns, singing as part of a congregation, or playing piano or organ, have an impact on a musician's pursuit of music as a career? The purpose of this study is to investigate the effects of religious backgrounds on musicians' career paths. In this study, an anonymous survey was given to the music majors and faculty of Montana State University. Questions were asked regarding participants' religious background, if the music was a significant aspect of this religious background, how they participated in religious music, and how music in religious contexts may have had an impact on their decision to be a musician. Follow-up interviews were conducted for people who stated music was a significant factor in their choice of career in order to discover more about why religious music was impactful for them.

Acknowledgments: USP - Undergraduate Scholars Program

Resistivity, Heat Capacity, and Magnetic Susceptibility of WO2I2

Caden Ingraham, Physics
Mentor(s): John Neumeier, Ecology

Van der Waals materials form strong bonds in one plane and weak bonds in the perpendicular direction, causing the formation of layers. These layers are easily separated, sometimes into atomically-thin sheets with physical properties that differ from the properties observed in bulk materials. WO2I2 is a Van Der Waals material whose properties have not yet been investigated. We will report on our measurements of the electrical resistivity, heat capacity, and magnetic susceptibility of WO2I2 .

Parallelized assessment of tau protein expression and transport in neurofluidics

Sarah Jarman, Chemistry & Biochemistry; Anja Kunze, Electrical & Computer Engineering; Zeynep Malkoç
Mentor(s): Anja Kunze, Electrical & Computer Engineering

In an ever-aging society, age related illnesses are becoming increasingly common, especially neurodegenerative diseases. One of these prominent cases is Alzheimer's Disease (AD). Symptoms of AD are described as memory loss, a sense of lacking spatial orientation, and an inability to learn new information, eventually leading to death. One hallmark of interest in an AD brain is the formation of protein clusters and tangles of amyloid beta as well as tau. The latter is hypothesized to cluster and accumulate in its hyperphosphorylated form in neurodegenerative brain cells. To better understand the mechanism of disease propagation, several methods can be used to replicate AD in vitro, such as stem cells and chemicals in contact with neural cells. Furthermore, microfluidics can be used to direct cell growth in an organized fashion for parallelized readout. In this study, okadaic acid (OA), one such AD-pathology-causing chemical, was used to induce hyperphosphorylation of tau proteins, eventually causing protein aggregation, and to monitor the disease progression over time in a microfluidics system. For live-cell imaging, we overexpressed fluorescent hTAU40 in primary cortical neuron cultures and monitored fluorescent signal distributions within the cytosol over a period of 24h.

Acknowledgments: USP - Undergraduate Scholars Program

Alcohol Use Disorder as a Function of Emotional Regulation and Thoughts About Historical Loss.

Morgan Jeffs, Psychology; Nievalinda Strong, Psychology ; Neha John-Henderson, Psychology
Mentor(s): Neha John-Henderson, Psychology

The psychosocial factors contributing to alcohol use disorders (AUD) in American Indian (AI) populations are not well understood. Trauma from European colonialism and genocide has been transmitted through generations leaving many AIs with frequent thoughts about historical loss. The current study aims to investigate whether the relationship between frequency of thinking about historical loss and AUD is moderated by emotion regulation strategies. We hypothesized that high use of emotion suppression in combination with high frequency of thoughts about historical loss would be linked to higher rates of AUD, whereas high use of emotion reappraisal may offset the relationship between high frequency of thoughts about historical loss and AUD. The sample consisted of 727 self-identifying AI adults. Although emotion suppression on its own was not significantly correlated to AUD, the interaction between historical loss and suppression was statistically significant in predicting scores on the Alcohol Use Disorder Identification Test (AUDIT) ($B=.14$, $t(655)=3.76$, $p<.001$), as was the interaction between reappraisal and thoughts about historical loss ($B=.16$, $t(655)=4.27$, $p<.001$). Our results suggest that emotion reappraisal may offset the relationship between thinking about historical losses and problematic alcohol use in American Indian adults.

In Vivo Analysis of Essential Genes in Mouse Liver Tissue Lacking the Two Major Cytosolic Reductases, Thioredoxin Reductase and Glutathione Reductase.

Aria Johnson, Nutritional Sciences – Pre-Medicine
Mentor(s): Justin Prigge, Microbiology & Immunology

In 2015, the first NADPH-independent source of disulfide reducing power was reported through the catabolism of methionine into reduced glutathione (GSH). Previously, all cytosolic disulfide reductase activity was believed to be dependent on NADPH-use by TrxR1 or Gsr and the transfer of reducing power by Trx1 or GSH/Glutaredoxins (Grxs). Having known NADPH-independent disulfide reducing power indicates there must be Grxs that participate in transferring power from GSH to essential targets and that other activities in the liver must be altered to support the disulfide reduction. There are four established Grxs, each of which we have individually targeted, along with all upregulated transcripts in the TrxR1/Gsr-null transcriptome. Previous studies with these mice revealed an altered transcriptome, dependent on which gene or combination of genes were deleted in mouse liver. Importantly, the lack of TrxR1, Txn1, or Gsr, alone or in combination results in up-regulation of compensatory genes, some of which may be critical to survival of hepatocytes. To this end, we have designed a system that allows us to interrogate which of the compensatory upregulated genes are critical to cellular survival. The CRIPSR/Cas9 system, in combination with recombinant AAV8 viruses will be used to disrupt all upregulated genes in TrxR1/Gsr-null liver cells. This project will involve DNA purification from mouse liver and subsequent PCR-based and Next-Gen Sequencing (NGS) analyses to ascertain which genes are essential to survival of hepatocytes in TrxR1/Gsr-null livers as compared to wild-type mouse liver.

Acknowledgments: USP - Undergraduate Scholars Program

Developing a relationship between binding kinetics and pressure drop within a point of use filter containing Silica Polyamine Composites

Sandra Kohl, Civil Engineering; Ranalda Tsosie
Mentor(s): Ellen Lauchnor, Civil Engineering; Ranalda Tsosie

Water contamination resulting from mining operations is a prevalent issue within the Western United States. Mines that have been abandoned and untreated cause toxic mine byproducts to leach into groundwater and surface water, specifically uranium and arsenic species. When these metal and metalloid species are present in drinking water, they can pose serious health risks to humans and livestock. To treat contaminated sources, solid phase extraction using Silica Polyamine Composites (SPCs) were utilized in this research to bind and remove uranium and arsenic species. Laboratory experiments were conducted to examine the equilibrium binding capacities of SPCs with uranium and arsenic in water samples and measure the rate of removal. Three SPCs with different surface chemicals and commercially available composites, were able to remove arsenic and uranium species, but at different rates of effectiveness. My work to understand the removal effectiveness of these materials has allowed a mechanical engineering capstone group to develop a housing unit for a point of use filter that will incorporate SPCs in their final design. In addition, data points such as pressure drop have been examined in a small packed column to understand flow parameters for effective composite retention time to create an effective rate of removal.

Acknowledgments: Other funding or support; Research Credit

That's Not What I Meant: Managing Racial Microaggressions in the Counseling Classroom

Sierra Lee, Health & Human Development; Jenna Coats, PLPC
Mentor(s): Anna Elliott, Health & Human Development

This Rocky Mountain Association of Counseling Education and Supervision Conference presentation is born out of the experiences shared by counseling students of color in a predominately white institution and the way they were harmed by faculty inaction when bigoted or micro aggressive actions were perpetrated in the classroom. Students and faculty in the program have since attempted to process what should be expected of students, regarding their professional dispositions and cultural humility, and the responsibility of faculty to call in/out harmful words and actions in the classroom. Presentation was developed from existing literature on student experiences and classroom dynamics regarding power, oppression, particularly in the context of counseling programs. This discussion-oriented presentation invited participants to reflect on their own experiences and positionality in the classroom, what they've learned about what has been effective or harmful. How do we continue to evolve as a profession to create spaces of courageous dialogue and respect, that genuinely takes in the context of student and faculty intersectional identities? We concluded with strategies on how to mitigate harm and increase equity when navigating these classroom interactions.

Acknowledgments: EHHD Student Travel Scholarship

Football, Black Lives Matter, and #ThreeLions: What the 2021 Euro Championship Tells us about the Politics of Race, Place-based Resentment, and the Representational Styles of English MPs

Mesa McKee, Political Science; Strandvold Knudsen, Political Science
Mentor(s): David Parker, Political Science

Members of the English football team expressed their support for racial justice and the Black Lives Matter movement by taking a knee during the Euro championship this summer—and were subjected to expressions of crowd disapproval, negative commentary from government ministers, and racist online abuse after losing to Italy in the finals. We explore in this paper how English MPs addressed the kneeling

of the English team and the subsequent racist abuse faced by English players Marcus Rashford, Jadon Sancho, and Bukaya Saka as a window into the politics of place-based (Cramer, 2016; Goodhart, 2017) and racial resentment in British politics. Many scholars have used social media to gauge the representational styles and position-taking of legislators (e.g. Silva and Proksch, 2021). We gathered data on the twitter feeds of English MPs for six weeks this summer to analyse the positions they took on the controversy. We anticipate that MPs representing less racially diverse and more deprived constituencies were less likely to make note of the controversy on social media. We expect that MPs representing Red Wall constituencies—whether Labour or Conservative—to be particularly unlikely to express support for the targeted players when compared to their colleagues. We conclude by considering how the politics of place, the rise of the culture wars, and identity conflicts (Sobolweska and Ford, 2020) in British politics create representational dilemmas within both the Conservative and Labour Parties in England.

Acknowledgments: USP - Undergraduate Scholars Program

The Impact of Music in Religious Worship in Bozeman, Montana

Mackenzie Meyer, Music
Mentor(s): Gregory Young, Music

Music has always been used as a bridge between the physical and the spiritual. Since antiquity, people have been using music as a way to engage in worship in many different religious contexts. In this study, I interviewed worship leaders from a variety of religious backgrounds to discover the impact of music on their worship experience. Participants were asked to share about their experiences with worship, their desired role for worship or devotional music within their congregations, and how they personally connected to the music presented during those times. The goal is to compare the role of music in various religious times of worship and the desired outcome of music in worship for congregants.

An Assessment of the Diversity, Composition, and Activity Patterns of the Mammalian Community in a Northern Rocky Mountain Foothills Rangeland Ecosystem

Morgan Monroe, Ecology; Ray Beaver, Animal & Rance Sciences; Lance McNew, Animal & Range Sciences
Mentor(s): Lance McNew, Animal & Range Sciences

Mammalian communities are an important part of functioning ecosystems as they have key roles in nutrient cycling, seed dispersal, and ecosystem engineering. Monitoring mammalian presence and diversity is vital in developing and implementing conservation management strategies. We used camera trap surveys to estimate the species richness of mammalian species at the Red Bluff Research Ranch in southwestern Montana. The Red Bluff Research Ranch is an 11,000-acre multi-use ranch with livestock grazing, as well as public access for hunting and recreation. We compiled a species inventory based on 41,896 images recorded at 20 camera trap locations over 5,576 camera trap days and we identified 13 wild mammalian species. The species identified ranged in classification from rodents to mesocarnivores to ungulates. We will further our research by evaluating the effects of anthropogenic activity on mammalian diversity by considering factors such as road proximity, livestock presence, and human activity at the camera trap locations. Analyses will also be conducted on changes in species richness of mammals due to seasonality. The results from this study will provide baseline data for future landscape-scale experiments conducted at the Red Bluff Research Ranch.

Living at Altitude: Associations with Sleep and Mental Health in Adolescents

Alexandria Montenegro, Psychology
Mentor(s): Cara Palmer, Psychology

Prior research in adults shows that living at higher altitude may increase risk for poorer psychological functioning, including greater daytime sleepiness (Stadelmann et al., 2013), and higher rates of depression and suicide (Ha & Tu, 2018). Despite these preliminary studies in adults, it is unknown how living at higher altitudes may be associated with sleep and mental health in adolescents, a period of the life-span when risk for the development of psychiatric disorders and sleep problems is high (CDC, 2019; Lee et al., 2014). The current study examined the relationships between altitude, daytime sleepiness, anxiety, and depression in an adolescent sample.

Participants included 125 adolescents (ages 10-17 years, M = 13.36, SD = 2.03; 46.4% female; 88% white, .8% American Indian/Alaskan Native, 1.6% Asian, 1.6% Other, 8% multiracial; 3.2% Hispanic/Latino). Participants were recruited to obtain a representative sample of teens from a rural state in the Mountain West region of the United States.

All participants lived at moderate altitude (M = 3,569, SD = 762, range = 1,938-5,325 feet). A series of regression models were conducted to examine associations between altitude, sleep, and mental health, while adjusting for age, sex, and income. Results suggest that altitude was not associated with depressive symptoms ($p = .29$) or anxiety symptoms ($p = .70$). After accounting for age, sex, and income, living at a higher altitude was associated with reports of needing more sleep ($\beta = .23$, $p = .03$). These findings replicate research in adults suggesting that altitude may increase sleep need.

Acknowledgments: NIH award numbers P20GM103474 and P20GM104417 McNair U.S. Department of Health grant award number P217A180134

Characterizing substrate induced conformational change in enzyme complexes.

Nic Murray, Chemistry & Biochemistry; Jenna Mattice, Chemistry & Biochemistry; Jay Malone, Chemistry & Biochemistry
Mentor(s): Brian Bothner, Chemistry & Biochemistry

During a reaction an enzyme can go through multiple conformational changes, or changes in shape. These changes in a protein are not well understood, but it is generally believed that substrate binding causes the intramolecular bonds in the protein to change and thus also change the enzymes affinity to substrates. Acetone carboxylases are a recently discovered class of enzymes that are not well researched. Acetone carboxylase (AC) is an enzyme in some microbes that reacts carbon dioxide/bicarbonate with a metabolite to further the microbe's metabolism. In this study we observed conformational changes of AC (found in Xanthobacter autotrophicus) with substrate binding using differential scanning fluorimetry, and intact hydrogen/deuterium exchange mass spectrometry. It was found that adenosine monophosphate, diphosphate, and triphosphate all have a global stabilizing effect on AC. While adenosine monophosphate also showed a local destabilization effect.

Acknowledgments: USP - Undergraduate Scholars Program

Watershed Cumulative Health Risk Analysis of Drinking Water Contaminants: Yellowstone Watershed, MT

Ingrid Peters, Liberal Studies Degree
Mentor(s): Margaret Eggers, Microbiology & Immunology; Adam Sigler, Land Resources & Environmental Sciences

This project analyzes data on surface and groundwater quality by river basin (at the level of Hydrologic Unit Code [Huc 8] in Park County, MT. The goal isto assess the cumulative health risks posed by public

water supplies using surface water sources or lifetime consumption of home well water. The project is supervised by Professor Margaret Eggers at MSU, who has outlined data cleaning and cumulative risk calculation methods based on previous water quality research. Data is retrieved from the Montana Ground Water Information Center (GWIC) database (https://mbmggwic.mtech.edu/). The water quality data graphs show the cumulative risk of lifetime consumption risk for each watershed and the percentage exceeding the relevant health standard for each contaminant. The goal is to interpret drinking water data relevant to citizens in Park County, MT who depend on wells and streams for drinking water, and to give the health department information on community health risks in the Yellowstone watershed. Preliminary results and methods have been presented to the Park County Health Department, and water quality flyers will be uploaded to MSU's Well Educated Program website for water quality education purposes. The data represents the Yellowstone Headwaters, Upper Yellowstone, Shields, and Yellowstone Lake HUC8 river basins in the Yellowstone watershed and this research will be continued into the fall.

Acknowledgments: USP - Undergraduate Scholars Program

Optimizing the Reaction Conditions for S34-Cysteine Biosynthesis using CysK Enzyme

Zoe Seaford, Microbiology & Cell Biology
Mentor(s): Ed Schmidt, Microbiology & Immunology

The Schmid Lab uses heavy isotope-labeled amino acids to analyze flux of 34S-containing metabolites in key redox cell pathways in the mouse liver using mass spectrometry. As 34S-labeled amino acids are extremely expensive, we have adopted methods for in-lab synthesis of heavy methionine and cystine for infusion into mice via jugular vein catheter. The newest synthetic method adopted by the Schmidt lab generates heavy cystine using bacterial-derived enzyme O-acetylserine sulfhydrylase, Na234S. My project for the semester has been optimizing the reaction conditions for this particular biosynthesis. The conditions being tested are temperature, enzyme concentration relative to reactants, time, and the use of reducing agent tris carboxyl ethyl phosphine (TCEP). Thus far we have found that incubating our CysK at 55 degrees has produced the highest amount of cystine. We have also found that this enzyme needs to be incubated at 55 degrees for longer than 24 hours. Beyond 24 hours product yield was not significantly increased. As a recent publication reports rapid, albeit small-scale synthesis using enzyme concentration relative to reactants greater than 50x that in our previous protocols, we have chosen to test various enzyme concentrations across different time frames seeking comparably efficient catalysis that are more cost-effective for bulk synthesis.

Acknowledgments: USP - Undergraduate Scholars Program

Music Therapy, Memory, and Happiness

Cindy Sharp, Music
Mentor(s): Gregory Young, Music

There is an increased amount of research over the past ten years discussing the effects of music therapy in patients with dementia. The challenging question initially was why musical memory was preserved in these patients. It has been difficult to evaluate the results of some of these studies due to small study groups and the difficulty in working with patients with cognitive impairment. This project will include a literature review of data available to determine how music therapy is incorporated and the effect of music therapy in these patients with cognitive decline. The goal is to reveal the positive impact that music may have in this group and increase awareness of this effect. The result of this review may increase discussion of cognitive decline and hopefully help caregivers another tool to help improve quality of life in this population.

Acknowledgments: USP - Undergraduate Scholars Program

The Effect of Music Therapy on IBS

Kaitlin Shaw, Music
Mentor(s): Gregory Young, Music

As many as 1.6 million Americans suffer from inflammatory bowel disease, which is a catch-all term for several very similar maladies, the most common of which are Crohn's disease and ulcerative colitis. Research has indicated that there is a substantial connection between digestive health and mental and emotional well-being, with the gut being referred to colloquially as the "second brain". Taking into account the well-known effects of music on mood, some researchers have begun investigating the idea that music therapy could influence and alleviate inflammatory bowel disease by way of the patient's emotions. Several case studies are available that support this conclusion, especially in the area of stress relief through music. During this project, I undertook a meta-analysis of existing research in the fields of music therapy and gastroenterology, with the goal of finding connections between the two that could be followed up on in empirical trials at a later date.

The Value of Walking the Beat: How Police Patrol Oversight Benefits Legislators

Talia Steel, Political Science
Mentor(s): David Parker, Political Sciece

Why should members of Congress engage in oversight? If we believe that members of Congress are most directly concerned with reelection, the motive for engaging in oversight of the executive is less than clear. It is costly, time consuming, and may not generate any results of note to share with the voters back home. That, at least, is the convention wisdom of McCubbins and Schwartz (1984). In this paper, we aim to revisit this question by conducting an empirical analysis of how individual members of Congress may benefit from engaging in police-patrol oversight. By comparing media appearances, number of interventions, and perceived political extremism during the 111th and 113th Congressional periods, we found that participating in oversight, although unrelated to a member's subsequent media appearances, does have a strong correlation with their level of political extremism. These results show that, when members engage in police-patrol oversight, they effectively send a partisan message about their initiative and willingness to advocate for their interests on a public platform. Contrary to the arguments of McCubbins and Schwartz (1984), engaging in police-patrol oversight does have benefits for reputation building, which gives theorists and the public at large a general sense of why politicians participate in these procedures and how they can be used as political instruments to promote their interests and advance their chances of reelection.

Acknowledgments: USP - Undergraduate Scholars Program

Screening Type III CRISPR Complexes for Enhanced Signal Amplification

Joseph Triem, Microbiology & Cell Biology; Trevor Zahl, Microbiology & Cell Biology; Blake Wiedenheft, Microbiology & Immunology
Mentor(s): Blake Wiedenheft, Microbiology & Immunology

Type-III CRISPR-Cas systems are programable RNA-guided detection systems that recognize RNA targets by complementary base pairing. Target RNA recognition activates a polymerase domain that selectively polymerizes adenosine triphosphate (ATP) into cyclic oligomers of adenosine (cOA). In bacteria, target detection-dependent polymerization of ATP amplifies the cOA alarm signal during an infection, and we recently repurposed these systems for sequence-specific detection of SARS-CoV-2. However, the sensitivity of these new CRISPR-based diagnostics is still insufficient for clinical applications. To improve sensitivity, we are screening type III complexes from Thermus thermophilus, Streptococcus thermophilus, and Enterococcus italicus to determine the rate of cOA synthesis (kcat).

Complexes that synthesize cOAs more rapidly will be incorporated into the diagnostic to increase overall sensitivity.

Acknowledgments: USP - Undergraduate Scholars Program & INBRE - IDeA Network for Biomedical Research Excellence

Effects of sori incubation temperature on Nereocystis luetkeana gametophyte & sporophyte development

Naomi Vliet, Education
Mentor(s): Brooke Weigel, Sadie Small

Climate change is affecting marine ecosystems around the world. Warming ocean temperatures have been linked to kelp forest declines, including Nereocystis luetkeana forests in the Salish Sea. However, the temperature tolerance of different stages of the N. luetkeana life cycle are not well established. We examined the effects of a short-term marine heatwave on N. luetkeana sori and subsequent microscopic life stages. We incubated sori at temperatures of 18°C, 20°C, and 21°C for 3.75 days, and grew gametophytes from each sori treatment at both 10°C and 16°C for 40 days. Gametophytes were able to develop normally and produce sporophytes from sori incubated at all temperatures, but gametophyte growth temperature had significant impacts on the life cycle. Gametophytes grew larger and at a faster rate at 16°C, but sporophytes developed faster and were more abundant when gametophytes were grown at 10°C. When sori were incubated at 21°C, gametophytes were more numerous but fewer sporophytes developed. Our findings suggest that sori can withstand temporary high temperatures and develop into gametophytes and sporophytes, but if gametophytes experience high temperatures the development of sporophytes may be hindered. A decrease in sporophyte development would disrupt the life cycle and could lead to loss of important kelp forest habitat. While all temperature treatments produced sporophytes, further research should identify the impacts of prolonged temperature stress (>3 days) on microscopic life stages.

Acknowledgments: McNair Scholars Program & NSF REU Grant

A Petrological & Geochemical Study into the Lava Creek Tuff of Yellowstone National Park

Victoria Wagner, Earth Sciences
Mentor(s): Stacy Henderson, Earth Sciences; Madison Myers, Earth Sciences

Yellowstone National Park contains two massive calderas formed from two super-eruptions. Yellowstone's most recent super-eruption formed the Lava Creek Tuff (LCT, 0.631 Ma). The project goal is to understand whether there are any geochemical differences between the two identified members of the LCT (LCT-A and LCT-B). Samples were collected from regions mapped as LCT-A and LCT-B, where this project will utilize petrologic and geochemical data from representative samples from each member. Geochemical differences in individual minerals or glass shards from these samples could imply multiple magma chambers feeding the eruption; a lack of differences could indicate a single, homogeneous magma chamber. We first imaged crystals from two samples in epoxy mounts using a scanning electron microscope. Observed zoning in sanidine is thought to be due to changes in trace element concentrations (e.g., Barium). Approximately 36 images were collected between both samples and broken into 5 visual populations regarding zoning. Zoning forms due to Barium content, where more Barium causes lighter zones, and less Barium causes darker zones. The LCT-A sample has several crystals with less zoning, while the LCT-B sample's crystals all contain some zoning. The differences may indicate differing initial magma compositions. Electron microprobe analysis will be carried out on both sanidine mounts using a Cameca SX-100 Electron Microprobe at Oregon State University. This instrument will measure major elements

(e.g. K2O, CaO, Al2O3, etc.) and barium concentrations in sanidines for geochemical description. The information collected will help give a better picture of any distinctions between members of the LCT.

Acknowledgments: USP - Undergraduate Scholars Program

The Application & Influence of Musical Involvement on Medical Practice

Heidi Watkins, Music
Mentor(s): Greg Young, Music

Connections and learning opportunities often appear where least expected, and the parallels between music and medicine provide a unique area for exploration. Listening skills, a detail oriented mind, and having an ability to work as part of a team are just a few of the many qualities shared by musicians and medical professionals. This study explores what specific skills are gained through musical involvement, how those skills come into play in medical practice, and if these commonalities are consistent across numerous physicians. In this study I interviewed multiple physician-musicians about their encounters with music education, and how those experiences impact their medical practice. Data from these interviews was then transcribed and coded to identify repeated themes, and descriptive statistics were used to analyze trends. Finding how musical involvement manifests in medical practice reveals often unrecognized elements of medicine, and provides insight into how medical education could be altered to better address these areas.

The Feasibility and Acceptability of Reactive Balance Training for Older Adults in Rural Communities

Justin Whitten, Health &Human Development; Dawn Tarabochia, Health & Human Development; Michell Grocke, Extension; Robert Griffin, Health & Health Development; David Graham, College of Education, Health, & Human Development
Mentor(s): David Graham, College of Education, Health, & Human Development

Reactive Balance Training (RBT) is an emerging balance training paradigm which is highly effective and requires a lower dose than traditional paradigms. However, whether it can be feasibly implemented in the community and accepted by older adults remains unknown. Therefore, the purpose of this project is to determine if RBT is a feasible and acceptable fall prevention paradigm for older adults. Firstly, we will determine the acceptability of a 6-week community-based RBT via a qualitative acceptability analysis within the Theoretical Framework of Acceptability. Secondly, we will compare the relative efficacy of RBT modalities in an 8-week clinical trial. Participants will be assigned to either manual or treadmill based RBT. Kinetics and kinematics will be recorded during training and pre/post testing sessions to quantify balance recovery performance. In addition to the Mini-BESTest, fall incidence will be monitored for the 12 months following training to determine the effect on real world falls.

Acknowledgments: INBRE - IDeA Network for Biomedical Research Excellence
This project was supported by the National Center For Advancing Translational Sciences of the National Institutes of Health under Award Number TL1 TR002318. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Strategies to Market Opera in Bozeman to Youth

Andrew Cantley, Music
Mentor(s): Greg Young, Music

Opera is a valuable and diverse art form that transcends time in its expression of the human condition through its combination of visual and audible storytelling. This project explores the marketing of opera to people aged 18 through 35 in the Bozeman area. Through survey and meta-analysis, this study will attempt to better understand negative perceptions of opera, strategies to shed these stigmas, current draws to

opera, and unique ways to target advertising to bring in new audience members of this age group. Implications for future research include a national study, comparisons with other countries, and a journal article in Opera News.

Restoration of a 19th-Century Clarinet

Karen Johnson, Music
Mentor(s): Greg Young, Music; Beth Antonopulos, Music

In 2021, a 19th-century clarinet was donated to MSU. This five-keyed predecessor to the modern clarinet provides a fascinating look into its history and use in American ensembles of the period. This particular clarinet is an anomaly, as more modern iterations existed at the time with additional keys to facilitate technique, although this could have been due to accessibility and cost. While some research has been done into the maker of the instrument, certain questions remain, such as: Exactly what it's made out of; the process of getting it restored to playability; and whether some players preferred this instrument to more modern clarinets of the time period. Implications for future research include restoring the clarinet, performance with period instrument ensembles and a video demonstration.

Acknowledgments: USP - Undergraduate Scholars Program

The Effects of Sound and Silence on Productivity

Elias Dunham, Music
Mentor(s): Greg Young, Music

In a world full of noise, many believe that silence is the best way to promote and support productivity, while others might prefer music or white noise for productivity. Some studies show that silence is beneficial as it allows the mind to solely focus on the task at hand, while others show that classical music boosts concentration and self-discipline. In this project, I will be collecting and examining the opinions and beliefs of undergraduate students and faculty on the impact that sound or music has on the brain and our productivity in a variety of situations. To compare and contrast the benefits and effects, I will ask participants their preference for sound, or lack of it, while studying, exercising, and relaxing to understand these influences. Implications for future research include studying brain activity with fMRI technology and analysis of the data.

Free Improvisation Pedagogy

Tristan Vernooy, Music
Mentor(s): Greg Young, Music

Improvisation is a vital part of a musician's experience, but it can often be overlooked in the classical tradition. Improvisation has profound pedagogical possibilities and musical benefits. However, due to its reputation as a self taught skill, non-jazz improvisation does not have nearly enough pedagogical literature. This project combines peer interview, personal experience, and scholastic research into a concise document that encourages students of all experience levels to engage with improvisation through exercises, theory, and guidance. The goal is to create a 'Free Improvisation Workbook' with exercises to get started and expand on existing skills. Trials will be conducted with fellow piano students, with a particular emphasis on those students who have very little experience improvising. Implications for future research include publishing a complete beginners guide to non-jazz improvisation as well as expanding the abilities of experienced improvisers.

Acknowledgments: USP - Undergraduate Scholars Program

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