RIT | College of Science
Munsell Color Science Laboratory

Program of Color Science
Munsell Color Science Laboratory

Annual Report 2024

From the Director: **Fasten Your Seatbelt**

Greetings from the dawn of 2025, as we reflect on 2024. I say "fasten your seatbelt" because we are approaching some curves in the road. Between tech industry realignment, government funding priority shifts, MCSL faculty approaching retirement, and RIT leadership changes, we can expect some racetrack-like g-forces coming up. Luckily, MCSL's robust international network of industry connections and strong endowments will steady our track as we react to the changing map and prepare for the future.

Looking in the 2024 rear-view mirror, I am proud to highlight the research accomplishments of our dedicated MS and PhD students. We have an especially full student office space lately, and I love seeing their skills develop as they work toward independence as color scientists! Please find in this report some highlights of the many ongoing projects on topics including imaging, AR & display systems, cultural heritage, material appearance, faces & avatars, color vision, and machine learning.

I'm especially happy to highlight that our own Dr. Mark Fairchild was designated Distinguished Professor, a well-deserved honor befitting his impact on RIT students and the entire color industry. He has been at the core of MCSL since its inception, and now that his well-earned retirement is nearing, the rest of us are already wondering how his shoes will ever be filled!

A big thank you to all of the individuals and organizations that have supported us financially or academically this year. We can't do it without you! If you would like to contribute in some way, please see the end pages with our fund-raising information, or contact me with project ideas.

Looking back at accomplishments and reviewing our growing list of alumni is always a treat. Please reach out to me anytime with comments, questions, or suggestions!

All the best! *Mike*

Photo @ American Museum of Natural History

Michael J. Murdoch, PhD
Director, Munsell Color Science Laboratory /
Program of Color Science
Head, Integrated Sciences Academy
michael.murdoch@mail.rit.edu

Distinguished Professor Dr. Mark Fairchild celebrating with College of Science Dean Dr. André Hudson

Distinguished Professor **Mark Fairchild**

Congratulations to MCSL's own Dr. Mark Fairchild, who was designated a Distinguished Professor, the highest academic title at RIT! University policy allows the Provost to confer this designation to a Professor who has:

"exhibited a record of singular excellence sustained over the course of their careers, as demonstrated by extraordinary scholarly contributions manifested in leading journal publications, books, or creative accomplishments; and … exemplary service that impacts one's professional field or the lives of others in extraordinary ways."

Mark received this honor from RIT President Dr. David Munson on April 10, 2024. MCSL's students and faculty all wish Mark a hearty congratulations for this well-earned honor!

Current Students and Visitors

Current MCSL Students

Saeedeh Abasi, PhD, CS
Dara Dimoff, PhD, CS
Tucker Downs, PhD, CS
Julianna Gross, MS, CS
Yanmei He, MS, CS
Sofie Herbeck, PhD, CS
Leah Humenuck, PhD, CS
Woojae Jung, PhD, CS
Sanaz Aghamohammadi Kalkhoran, PhD, CS
Zilong Li, PhD, CS
Andrea Avendano Martinez, MS, CS
Likhitha Nagahanumaiah, PhD, CS
Eddie Pei, PhD, CS
Alireza “Nima” Rabbanifar, MS, CS
Emily Rooney, PhD, CS
Soroush Shahbaznejad, PhD, CS
Vlad Simion, MS, CS
Sahara Smith, PhD, CS
Yuan Tian, PhD, CS
Fernando Voltolini De Azambuja, MS, CS
Abby Weymouth, PhD, CS
Xinmiao Zhang, MS, CS
Shuyi Zhao, PhD, CS

Undergraduate Exchange Students

Sander Tøkje Hauge, NTNU
Kjetil Karstensen Indrehus, NTNU
Martin Hegnum Johannessen, NTNU

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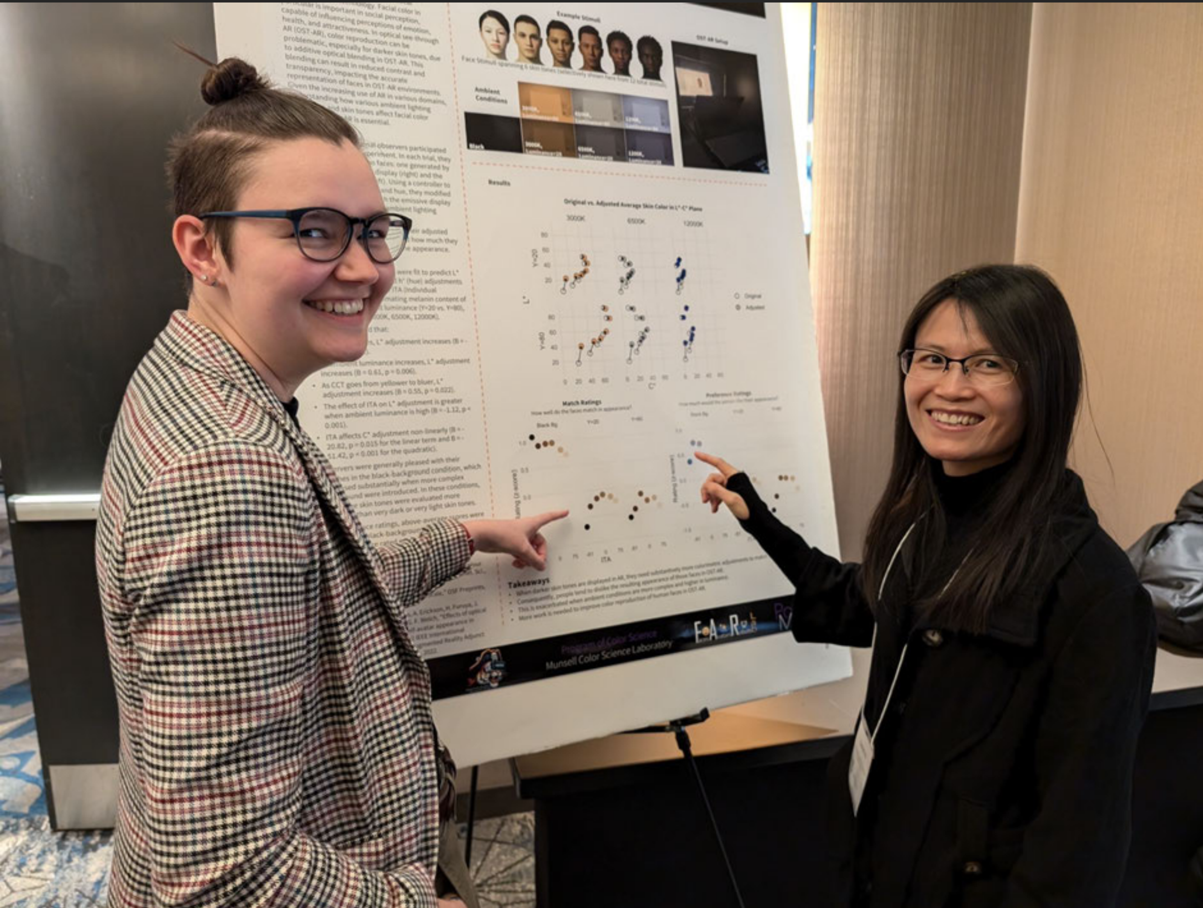
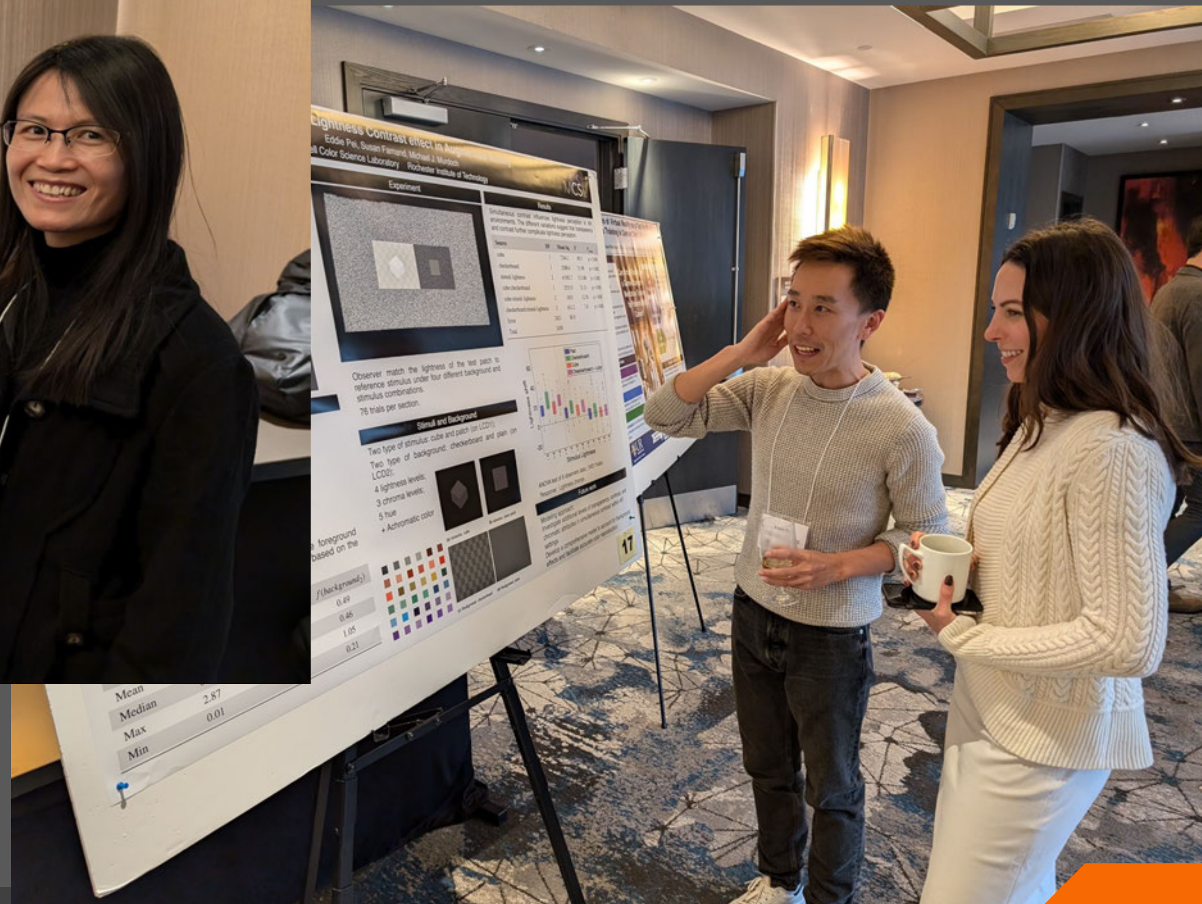
Jim Ferwerda, Imaging Science
Joe Geigel, Computer Science
Andy Herbert, Psychology
David Long, Motion Picture Science

PoCS/MCSL Board of Counselors
Ellen Carter, Color Research & Application
Scot Fernandez, YRC Worldwide
Francisco Imai, Apple
Tom Lianza, Sequel Color Science
M. Ronnier Luo, Zhejiang University
Ricardo Motta, Google


Example Stimuli
Results
Match Ratings
Takeaways
Program of Color Science
Munsell Color Science Laboratory


Experiment
Results
Stimuli and Background
Mean
Median
Max
Min
2.87
0.01

Research Highlight: **Mobile Phone Cameras and Color Accuracy for Cultural Heritage**

As part of the Academic Partnership for Excellence in Color Science (APECS) joint project between the Munsell Color Science Lab and the Norwegian University of Science and Technology (NTNU) – a project that is intended to enrich the academic experiences for students at both institutions – Leah Humenuck was invited to the Colour Lab at NTNU to work with Professor Sony George to research the application of mobile phone cameras and color accuracy for documenting cultural heritage items. During her three-month stay, she imaged a variety of items, including tapestries, historic photographs, and paintings, at institutions around the country, including the National Museum of Norway. Additionally, while she was there, she also created a survey on the topic of cultural heritage documentation, which received over 300 participants. The results from this research and the survey will be the subject of upcoming journal and conference publications.

Leah Humenuck, Sony George,
Susan Farnand

Research Highlight: **Predicting BeyondRGB results using filtered lights**

BeyondRGB is a software application developed in collaboration between the Munsell Color Science Lab and software engineering students and faculty. It is an application designed for accessible cultural heritage imaging using pairs of RGB captures. Users input two sets of images captured under different lighting conditions, and the software combines them into a single, color-mastered image. The accuracy of the final output depends on the lighting conditions used. This research investigates using $3 to $10 lighting filters that can be easily integrated into the existing imaging workflow. The goal is to create a tool that selects the best filters for color accuracy to pair with any given light.

Sahara Smith and Susan Farnand

Research Highlight: **Color constancy in virtual environments with head-mounted and flat-panel displays**

One of the goals of VR is to closely approximate perception of the real world. In real life, variations in lighting conditions can significantly influence how colors are perceived, both over time and in different environments. However, the human visual system automatically compensates for these changes so that constant color perception is largely maintained. This process is called 'chromatic adaptation', whereby we tend to discount the color of the illuminant so that objects' colors appear consistent across variable lighting conditions. Little research has been done to investigate how color constancy manifests in VR, in which we view a virtual environment through an emissive screen. This research evaluates how changing illumination conditions in virtual environments affects color appearance within a head-mounted VR display versus a conventional flat-panel display. This research will enhance our understanding into how color perception functions in virtual environments and may contribute to developing more immersive VR experiences.

Andrea Avendano Martinez,
Chris Thorstenson, Michael J. Murdoch

Research Highlight: **Evaluating color perception with tinted eyewear**

Tinted eyewear is useful in outdoor environments to protect against ultraviolet radiation and manage light reaching the eye. However, the design of such eyewear might also selectively influence color perception. The current research evaluates different tinted eyewear, with lenses having specialized characteristic spectral transmissive properties, that are expected to consequently impact color perception (e.g., contrast sensitivity and perceived chromatic color differences). The current work aims to explore how the design of tinted eyewear could be expanded to facilitate different kinds of visual tasks in outdoor environments, and how to compute metrics designed to predict such visual differences.

Likhitha Nagahanumaiah, Shuyi Zhao,
Chris Thorstenson, Susan Farnand

Research Highlight: **Individual Color Matching Functions in Image Reproduction**

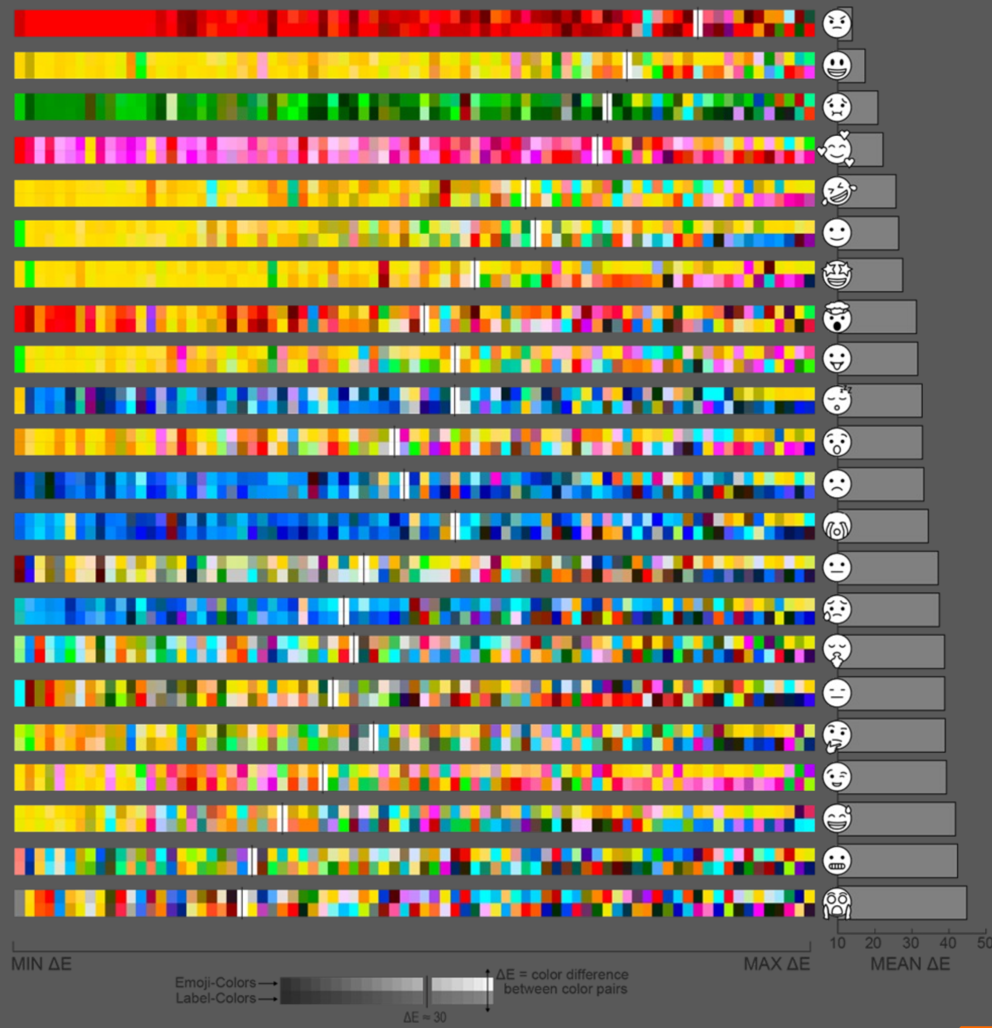
Human perception of color varies between individuals, raising the question of how well the standard color matching functions (CMFs) perform for individual observers in image reproduction. The goal of this research is to explore the relationship between CMFs and both fidelity and preference in the image reproduction pipeline. Three experiments were conducted: an experiment to estimate categorical individualized CMFs, an image fidelity experiment, and an image preference experiment. The results show that the CMFs influence the accuracy of image reproduction, however, preferences are affected by other factors in addition to CMFs. The findings offer insights into the limitations and potential implications of relying on using standard CMFs in image reproduction technologies.

Eddie Pei, Susan Farnand,
Michael J. Murdoch

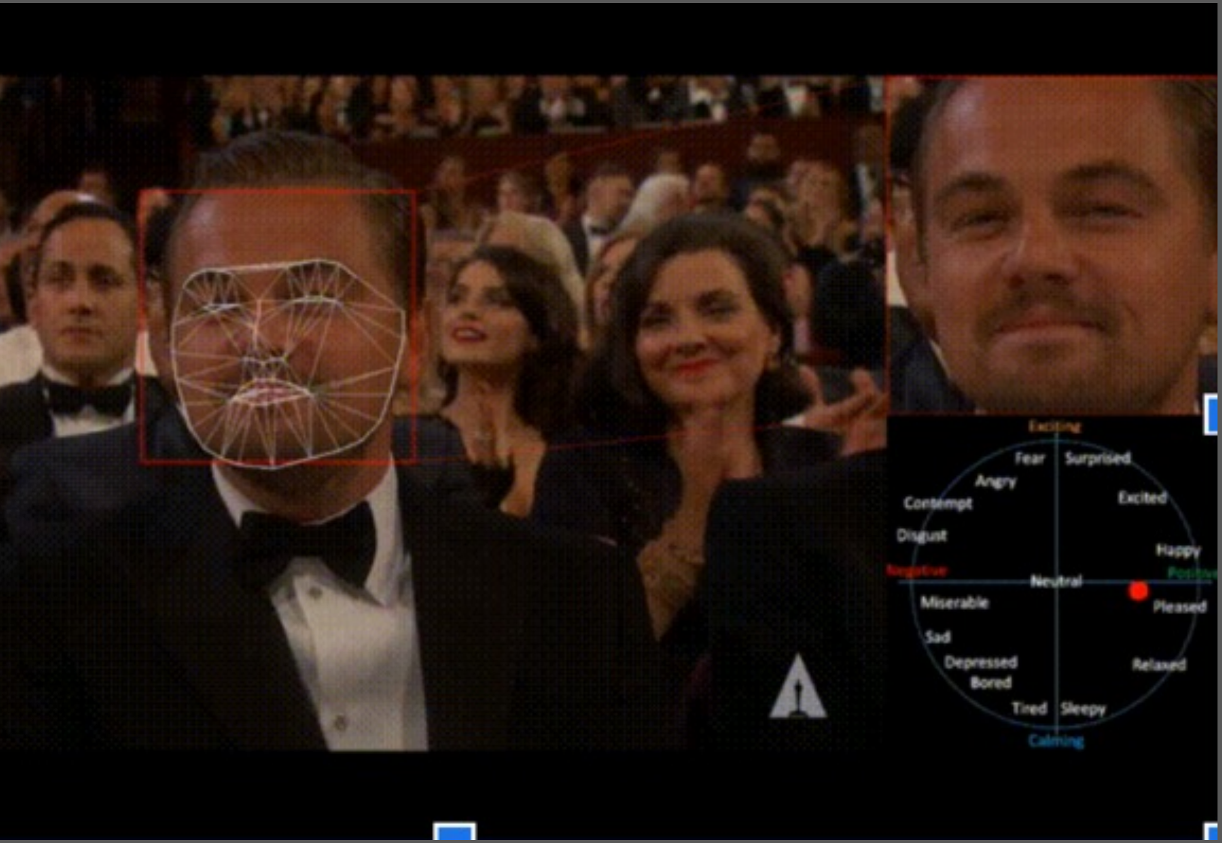
Research Highlight: **Color association correspondences between emojis and emotions**

Emotion concepts are abstract, but we often communicate about emotion using visual media. Emojis translate concrete facial expressions (smiles, frowns) to convey abstract emotion concepts (happy, sad). Emojis also often incorporate color to emphasize emotion concepts. This inclusion of color as a visual cue to emotion likely suggests that color can meaningfully facilitate emotion communication via visual media. This research seeks to better understand correspondences between emojis, their perceived emotion concepts, and their color associations. The research shows some instances of high correspondence between emoji-color and label-color associations (e.g., both angry emojis and the concept 'angry' are highly associated with red). However, there are also several instances where these associations do not correspond well (e.g., colors associated with a nervous emoji do not correspond well to colors associated with that emoji's label). The current work investigates factors that might predict these differences, as well implications for perception and cognition.

Gwynneth Buckton, Tina Sutton, Chris Thorstenson



Research Highlight: **Modeling Emotion using Facial Expressions from Video**



Attention-based emotion estimators aggregate video embeddings and output information regarding arousal, the state of alertness, and valence, the degree of attractiveness or aversiveness towards a subject. It is hypothesized that the addition of physiological signal estimation features could increase the versatility of a pre-existing model, EmoNet. This study aims to validate a dataset (DEAP) to train an improved version of EmoNet. Facial video of participants will be recorded and emotions will be rated in terms of arousal and valence using the Self-Assessment Manikins test. Both ground truth and non-contact based heart rate and blood volume plethysmography (BVP) information will be recorded while emotions are elicited with music video stimuli. Video plethysmography (VPG) technology will derive heart rate information from faces by detecting subtle oscillations in the hue channel of the HSV color space in the HealthKam Afib app. Physiological data estimation will be integrated into a deep neural network following dataset validation.

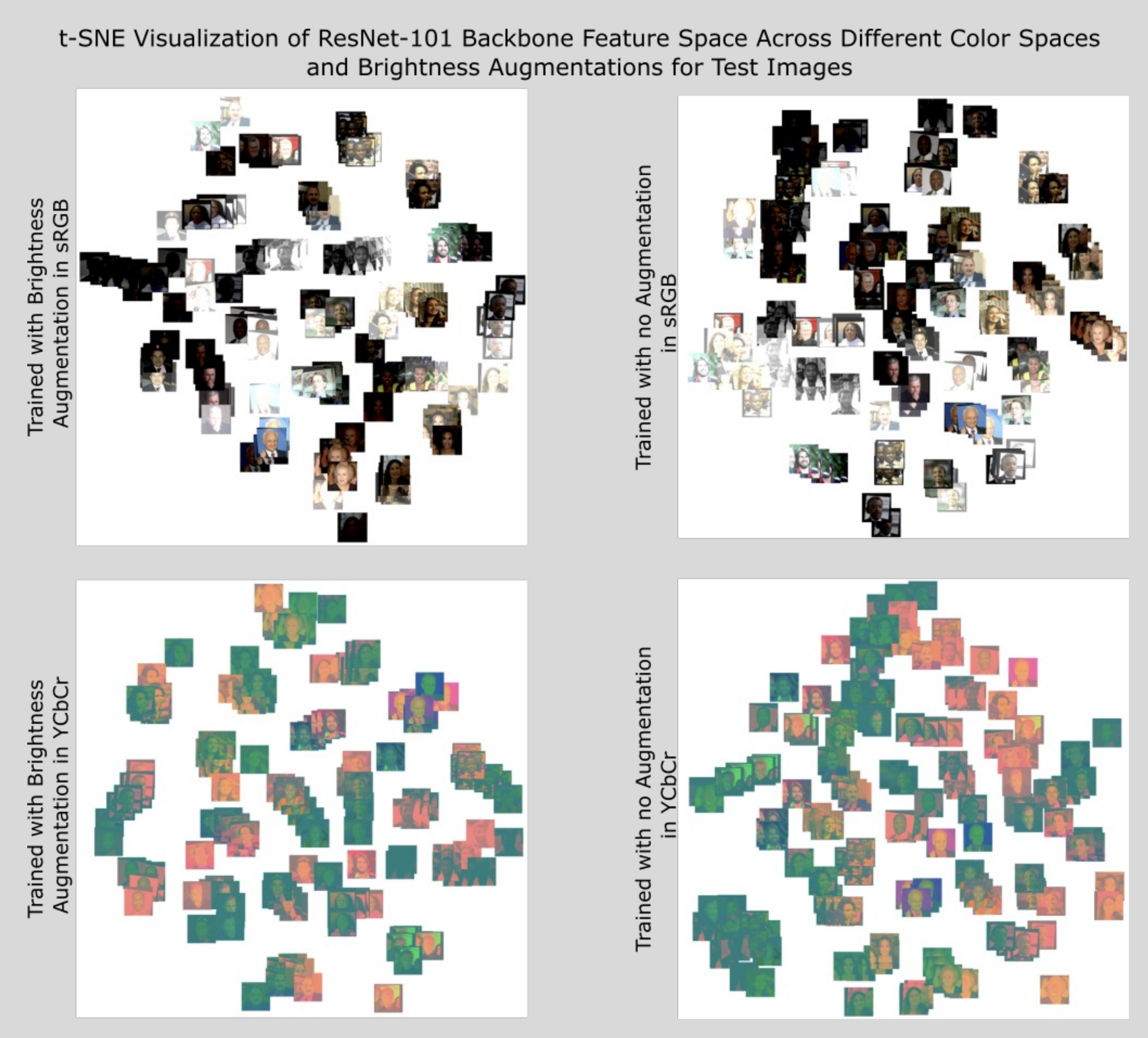
Emily Rooney, Ferat Sahin, Chris Thorstenson

Research Highlight: **Computation of a G_0-Referenced Lightness Metric**

This study introduces a G_0-referenced lightness metric, L^*_{G0}, to address limitations in the traditional CIE L* scale when dealing with highly saturated colors. By defining G_0 luminance at which a color transitions from reflective to self-luminous, the method directly incorporates the Helmholtz-Kohlrausch effect, wherein more saturated colors appear brighter at equal luminance. G_0 luminance is computed using MacAdam optimal colors as chromatic anchors, generating a lookup table of reflectance spectra that can be used for varied illuminants and color matching functions. Results show that L^*_{G0} better aligns with perceptual observation than CIE L* across multiple color order systems (Munsell, NCS, DIN), particularly for hues like red and purple. This improved modeling of perceived brightness has broad applicability in color science and related industries. The accompanying images illustrate color to grayscale conversion using luma (weighted combination of nonlinear RGB), CIE L*, and L^*_{G0} (from left to right).

Sanaz Aghamohammadi Kalkoran and Mark Fairchild

Research Highlight: **Unveiling the role of color science in deep learning**



Color is a visual property which is a rich source of data that influences deep learning performance across multiple domains. Understanding color perception, scene composition, and color space transformations enhances model accuracy, generalization, and fairness. As a first step to our investigation, we evaluated the role of color-based augmentations and color spaces in improving semantic skin segmentation accuracy. We analyzed brightness, contrast, and saturation adjustments in sRGB, YCbCr, and CIELab using an FCN-ResNet101 CNN model. Our results show that relying solely on sRGB-based augmentations and geometric transformations limits model generalization. Models trained with diverse color augmentations performed better, particularly in over- and under-exposure conditions, with YCbCr showing notable improvements. These findings highlight the importance of optimizing dataset color distribution through targeted augmentations and color space selection to enhance model robustness.

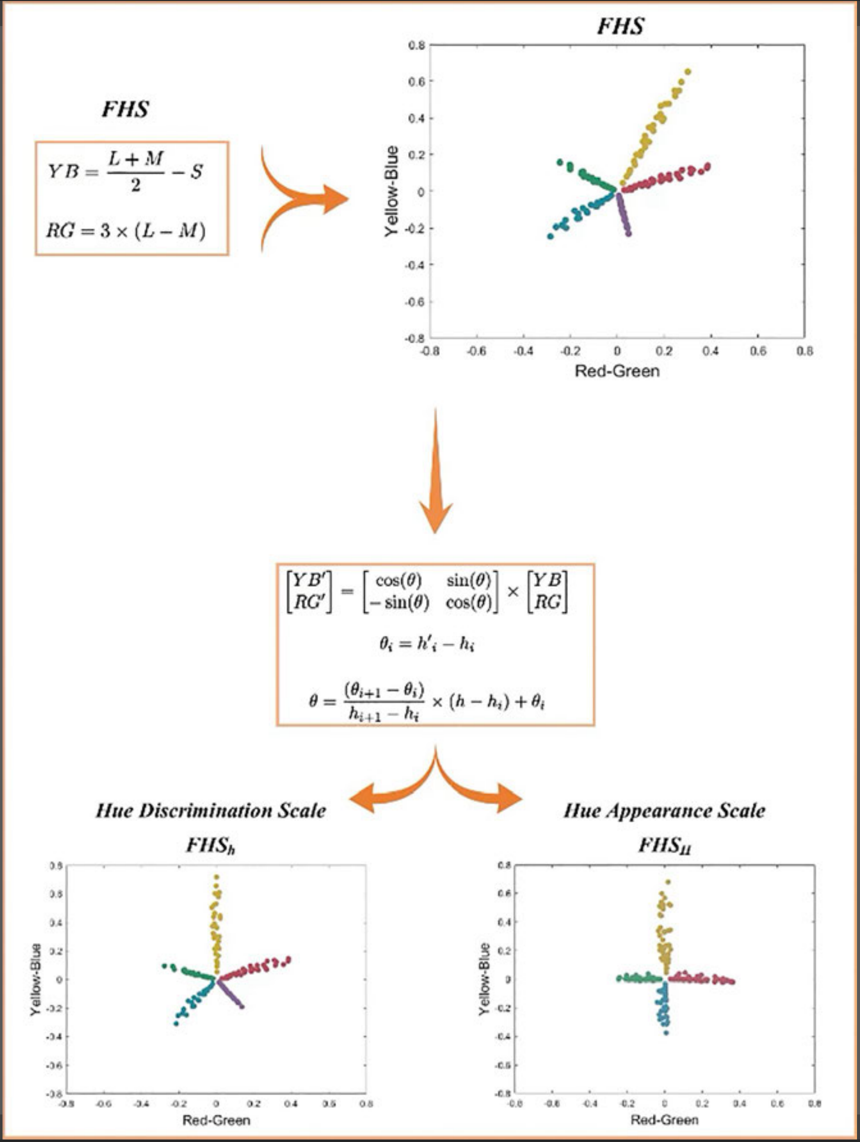
Soroush Shahbaznejad, Nima Rabbanifar, Mekides Assefa Abebe

Research Highlight: **Trichromator: CMFs the Old Fashioned Way**

Human color vision varies on an individual basis. Although standard color matching functions (CMFs) exist to model the average person's color vision, these will not produce the most accurate representation or reproduction of how an individual perceives color. Individual CMFs can be obtained through measurement (e.g., asking someone to match monochromatic or white lights with a combination of LED primaries) and/or modeling (e.g., using observer age and other factors affecting vision). Due to the number of color matches required to determine individual CMFs through measurement alone — and the time-consuming, equipment-intensive experiments this entails — modern approaches typically aim to use a minimal set of matches along with sophisticated modeling. However, no direct comparison has been made between the results obtained from measurement alone and those from novel modeling methods. The proposed study will use the MCSL's soon-to-be-functional trichromator (an optical setup used for color-matching experiments), alongside existing parameterized modeling methods from the literature, to conduct an in-depth evaluation of the state of the art in estimation of individual CMFs.

Sofie Herbeck and Michael J. Murdoch

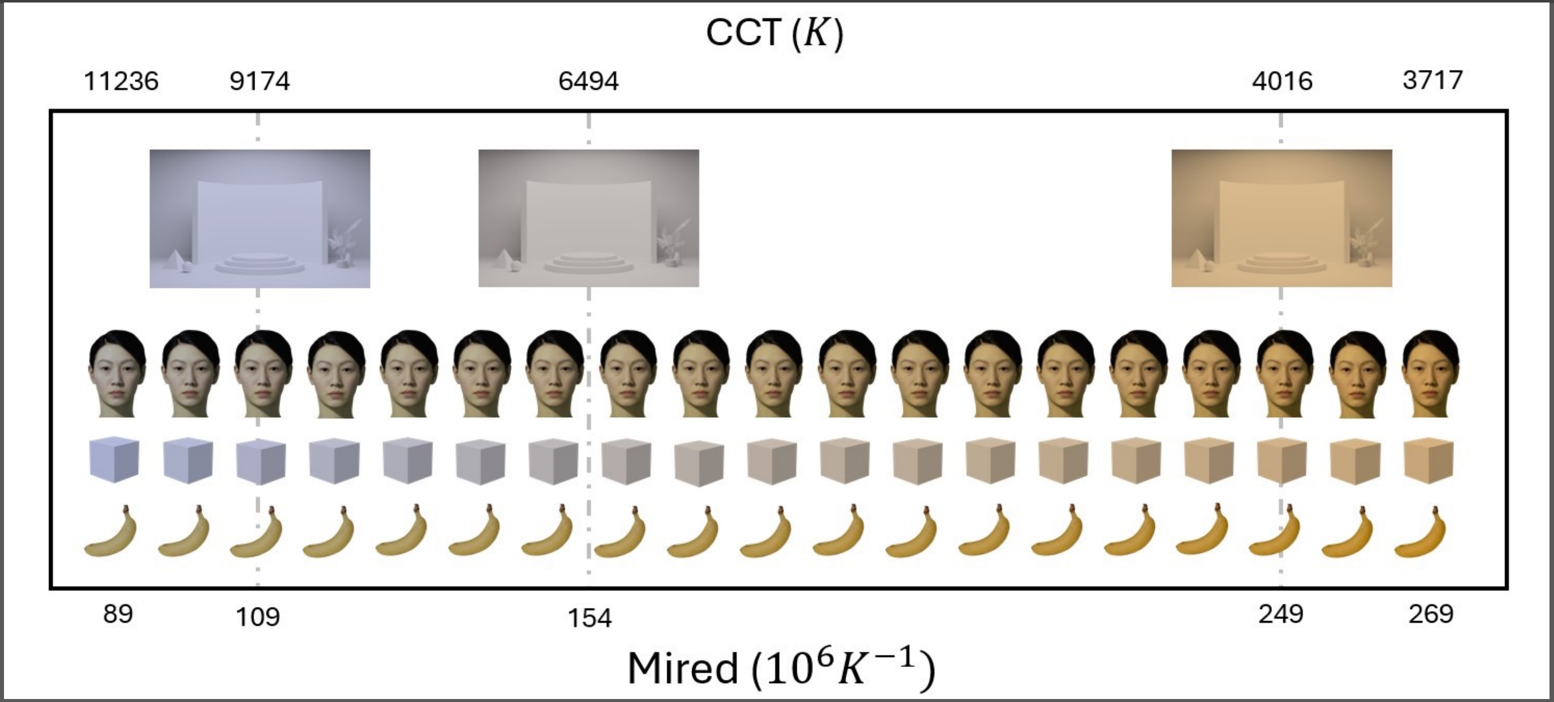
Research Highlight: **Fundamental Color Appearance Scales**



Two fundamental hue scales for hue discrimination (FHS_h) and hue appearance (FHS_H) purposes, developed previously, were improved to have a better performance. These scales were then evaluated using traditional data sets and three visual experiments. Both scales showed good hue linearity. The FHS_h predicts hue discrimination well while the FHS_H successfully describes hue appearance. The improved FHS model with both scales is shown schematically in the accompanying figure. A journal paper on this topic has been submitted. A second part of this dissertation research on fundamental appearance scales has been the development of fundamental brightness and lightness scales. These scales are built directly based on cone fundamentals. The lightness scale performs well in comparison with CIECAM16 and is being extended and improved predict brightness and account for the Helmholtz-Kohlrausch effect and the Stevens effect.

Saeedeh Abassi and Mark Fairchild

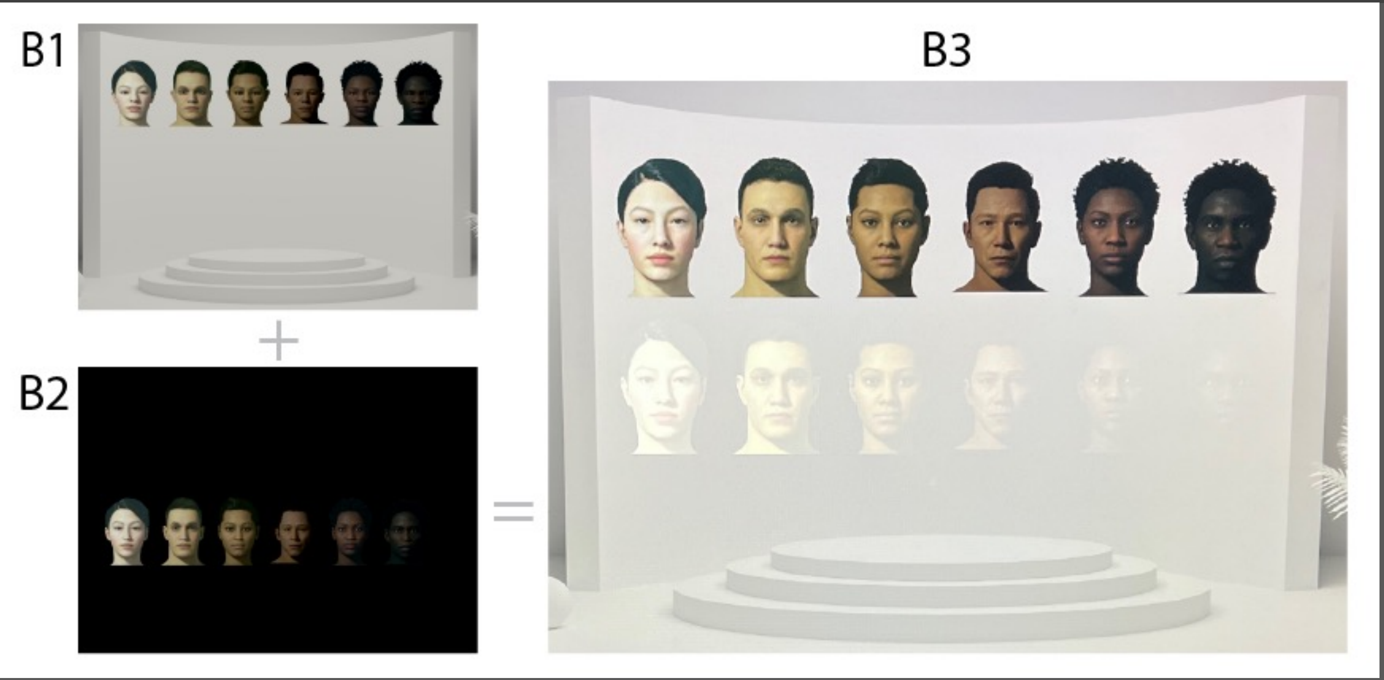
Research Highlight: **Perceptual thresholds of facial lighting in emissive and AR displays**



One existing challenge in augmented reality (AR) is that one's surrounding physical environment and virtual content often comprise disparate lighting conditions, which may be detrimental to AR experiences when merged together. However, it is not currently known "how" different these lighting conditions need to be before people can discriminate them, or before it becomes detrimental to user experiences. This work evaluates the effects of different skin tones, lighting conditions, and AR display methods on visual thresholds for perceiving lighting matches, mismatches, and preferences. This research aims to provide insights into improving AR rendering for mixed-illumination environments, particularly with regard to creating more inclusive social spaces.

Xinmiao Zhang, Sofie Herbeck, Chris Thorstenson

Research Highlight: **Facial color matching in optical see-through augmented reality**



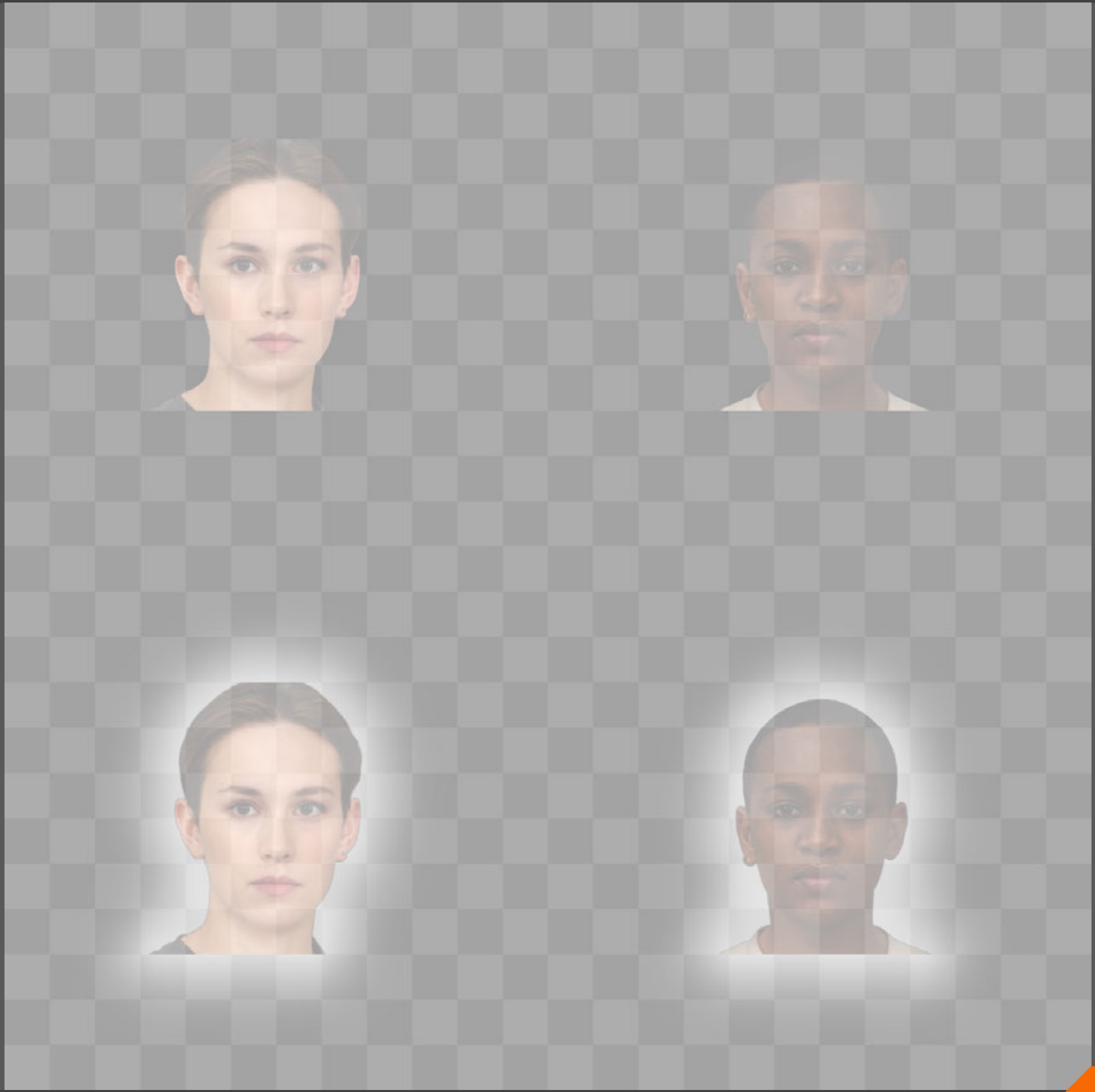
Displaying virtual human faces is a widespread practical application of AR technology, which can be challenging in optical see-through AR (OST-AR), due to limitations in its color reproduction. Specifically, OST-AR's additive optical blending introduces transparency and color-bleeding, which is exacerbated especially for faces having darker skin tones, and for brighter and more chromatic ambient environments. This research investigates how participants adjust colorimetric dimensions of OST-AR-displayed faces to match the color of the same faces viewed on a conventional emissive display. These adjustments were made for faces having six different skin tones, while under different simulated ambient luminance ('low' vs. 'high') and chromaticity (warm, neutral, cool). The current work is expected to facilitate virtual human face reproduction in AR applications and to foster more equitable and inclusive extended reality environments.

Yanmei He and Chris Thorstenson

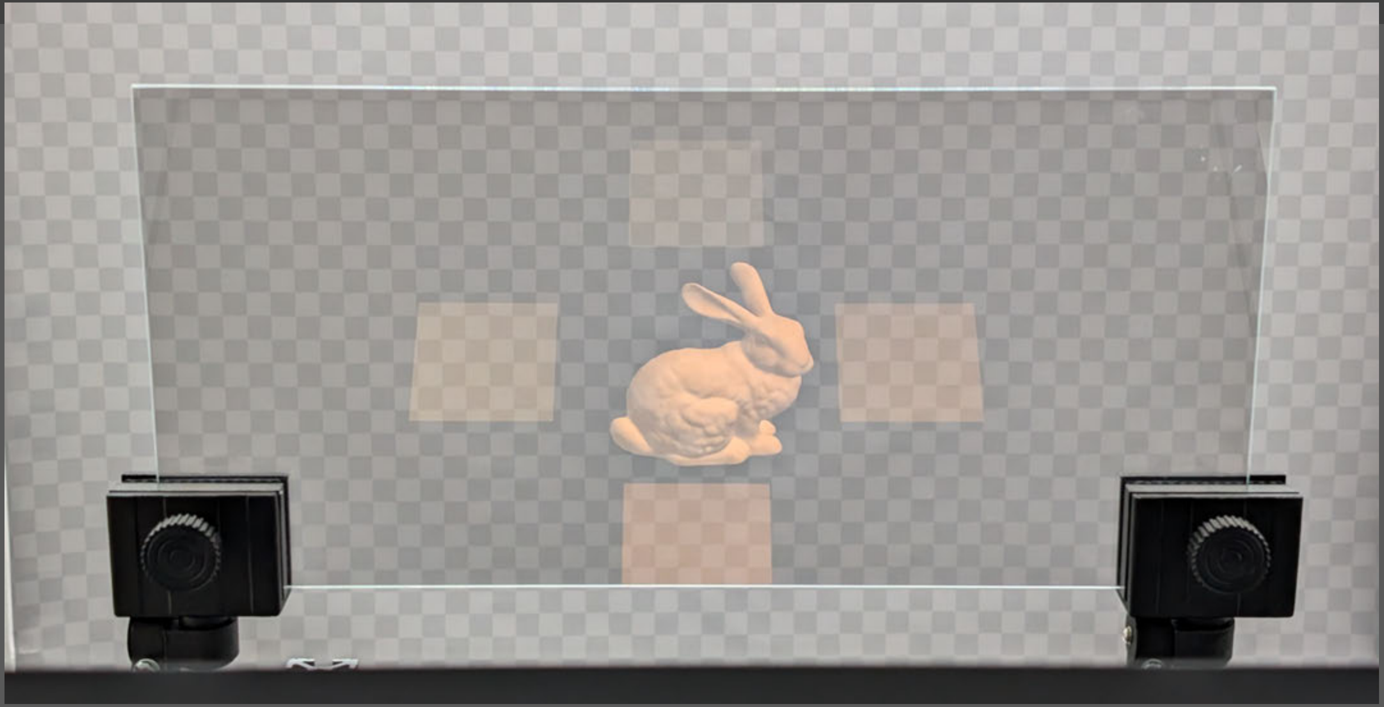
Research Highlight: **Corona Effect in Augmented Reality**

In optical see-through augmented reality (OST-AR) displays, physical transparency limits the visibility of dark stimuli with the practical result that low-luminance images become invisible in transparent displays. A possible solution is to simply make them brighter, but that also makes them less natural. Recent studies, inspired by lightness induction effects, show that simple image manipulations such as white borders and outer glows can help make dark objects appear darker and more opaque. In this work, the practical value of known, inter-related effects including the glare illusion, Cornsweet illusion, and simultaneous contrast are explored. The results show the strongest useful effect from an outer glow around an image alpha matte, suggesting an eclipse-like corona. With additional optimization, this promises simple and impactful improvement to visibility and visual quality in future OST-AR interfaces.

Michael J. Murdoch



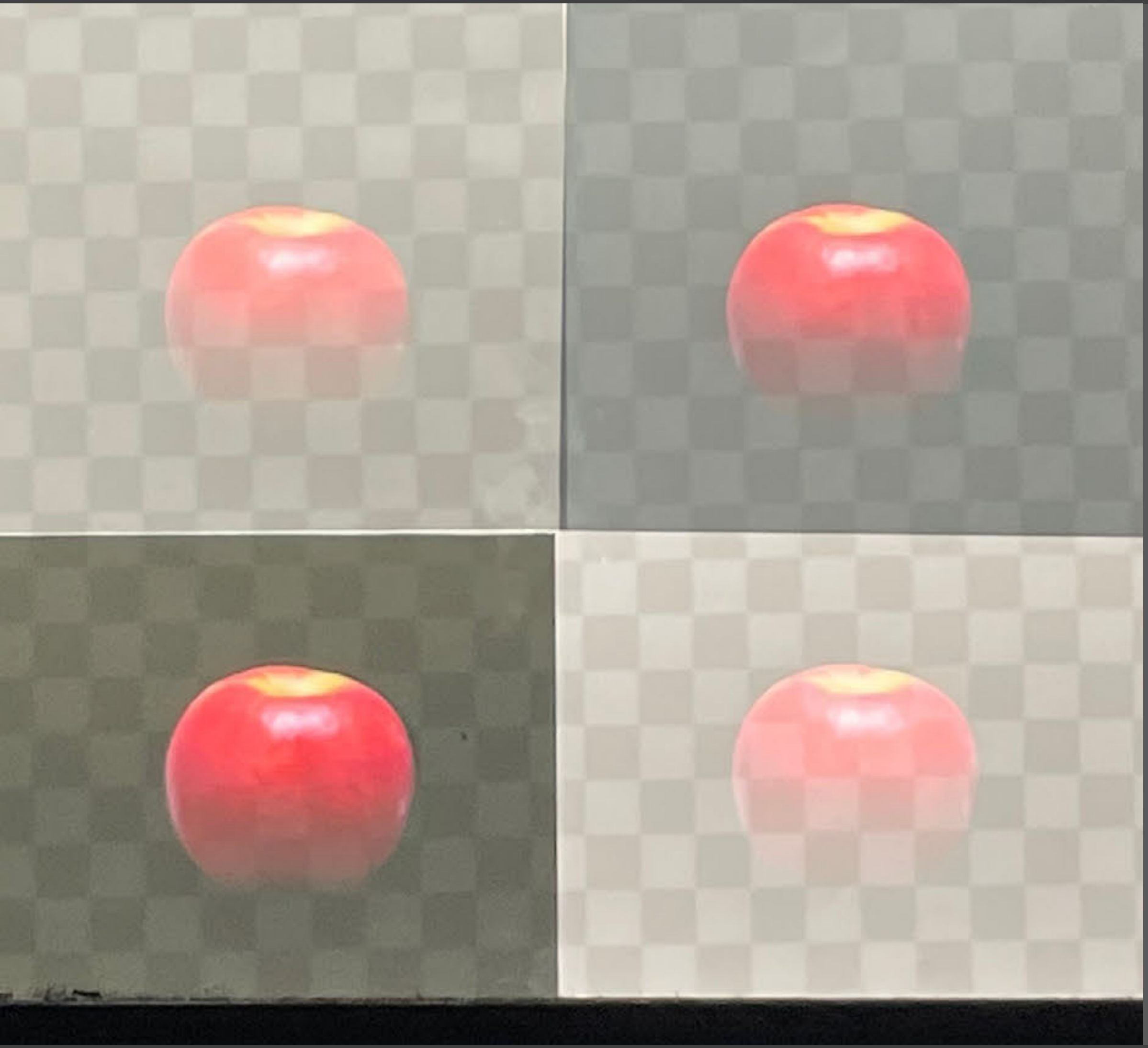
Research Highlight: **Chromatic Adaptation in Augmented Reality**



As augmented reality systems continue to develop, it is important to characterize visual perception within this framework, whether to present virtual elements accurately or manipulate them for a desired effect. Chromatic adaptation is a significant part of visual perception which is not well understood in the context of augmented reality. Further complicating the issue, environmental lighting in AR applications is rarely constant, as illumination shifts and users move in the real world, and adaptation has not been thoroughly studied under such conditions. Ongoing experiments with dynamic lighting and transparent AR stimuli are designed to measure achromatic appearance while the AR stimulus changes color. Both constant and dynamically changing illumination conditions are being examined. The data will be used to create a model of chromatic adaptation that can account for dynamic changes in both the illumination and augmented reality stimulus.

Abby Weymouth and Michael J. Murdoch

Research Highlight: **Perceived Contrast in Augmented Reality**



Recently we systematically examined the interplay between ambient lighting conditions and ND filter attenuation of the background on the perceived contrast of optical see-through AR (OST-AR) content. In this study, the OST-AR system has an illuminated checkerboard background mode within a light booth, allowing precise control over illuminance levels ranging from near-zero lux to over 10,000 lux. A diverse array of stimuli—including fruits, human faces, real-life objects, simple geometry and animated 3D objects—is presented to participants, who are tasked with rating the perceived contrast. By employing ND filters (ND3, ND6, and ND9) to modulate the background contribution, the experiment facilitates controlled cross-comparison of equivalent illuminance conditions and evaluates whether established models are applicable in AR contexts. The development of a comprehensive mathematical model that integrates factors such as ambient and display luminance, spatial frequency, and filter attenuation is in progress. The goal is a robust framework for understanding and controlling perceived transparency and contrast in OST-AR.

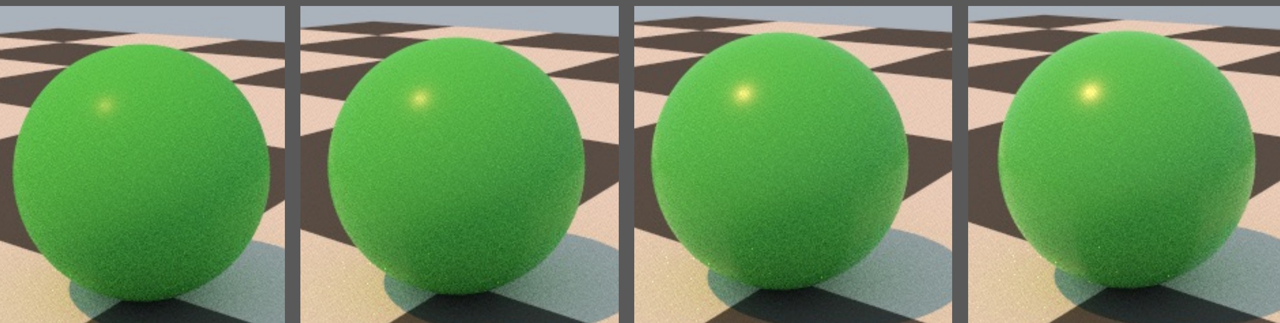
Zilong Li and Michael J. Murdoch

Research Highlight: **Perceived Dynamic Range of Images on Consumer Displays**

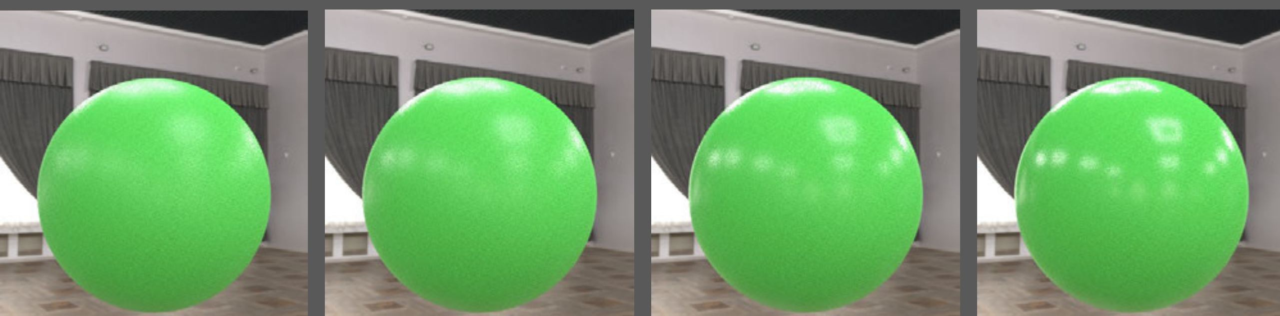
Recent advances in consumer displays on smartphones, tablets, and laptops allow relatively easy presentation of images with extremely high dynamic ranges. This furthers the need to understand the human perception of dynamic range in realistic viewing conditions. This research, as a part-time M.S. thesis, aims to explore HDR imaging through a series of visual experiments being designed to better understand the the tradeoffs between white luminance, black luminance, and their ratio in producing an overall experience of dynamic range. For example, does a brighter image with a lower luminance ratio actually appear to have a higher dynamic range than a dimmer image with a higher luminance ratio? The accompanying images provide an example of such a tradeoff.

Fernando Voltolini de Azambuja and Mark Fairchild

Research Highlight: **Gloss Appearance & Editing**



Contrast gloss increase ->



Gloss Sharpness increase ->

Appearance editing is essential in various applications, such as cultural heritage restoration and archiving, game design, industrial design, and more. Appearance editing encompasses tasks such as adjusting image colors, modifying object materials in images, and editing virtual 3D scenes. To simulate a real-world scene, appearance modeling is required, ranging from lighting or environment map, materials and shapes of objects, to virtual capture of the scene. One category of material editing depends on all the elements in the scene, lighting, object, virtual camera and the appearance modeling. Users modulate both parametric and measured BRDFs, moreover, spatially-varying BRDFs. The goal of the study is to develop a perceptual related gloss editing pipeline. Therefore, we firstly will establish a quantitative relations between parametric BRDF and perceptual gloss attributes (glossiness, contrast gloss, gloss sharpness, and etc.), for different illuminations, shapes and materials. Then, we will address the question about how users assess gloss of objects from their memories, which can be divided into two categories: objects from working memories, and familiar objects from long-term memories.

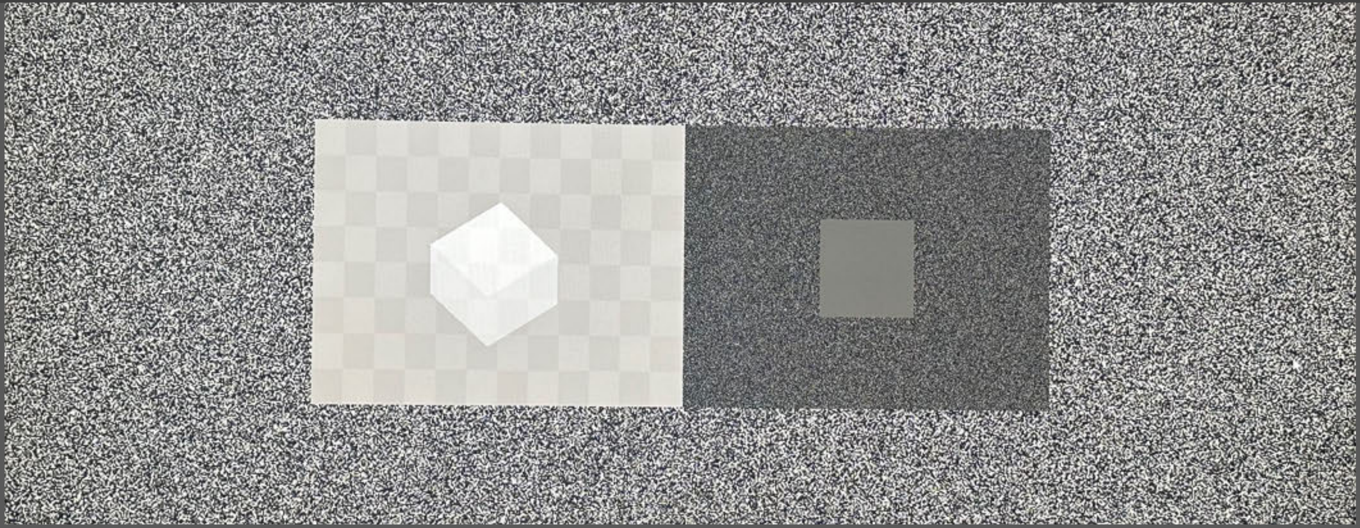
Yuan Tian and Michael J. Murdoch

Research Highlight: **Extending CIECAM16 to Account for Simultaneous Contrast**

Simultaneous contrast is the phenomenon in which the background influences perceived color. Existing color appearance models (CAMs) are inadequate in fully capturing this effect. This research aims to provide a deeper understanding of the simultaneous contrast effect and to extend the state-of-the-art color appearance model, CIECAM16, to better account for this phenomenon. By conducting three experiments, we empirically assessed the effects of simultaneous contrast on chroma, hue, and lightness. The findings revealed that a stimulus' perceived color attributes changed significantly depending on the color properties of the background. Based on these results, we extended CIECAM16 to account for the simultaneous contrast effect. The results demonstrated that the extended CIECAM16 model significantly improved the ability to predict color appearance while accounting for simultaneous contrast and offered closer alignment with observed findings and visual mechanisms. This research enhances the understanding of simultaneous contrast and contributes to improving the CIECAM16 model.

Eddie Pei, Susan Farnand, Mark D. Fairchild

Research Highlight: **Simultaneous Contrast in Augmented Reality**



This research investigates simultaneous lightness contrast within optical see-through augmented reality (OST AR) systems. The AR system has a transparent display that induces a layered perception, a unique feature of AR environments. Stimuli and background configuration can add visual cues to the layers, affecting lightness perception. Four experiments were conducted to explore the factors influencing simultaneous lightness contrast, including the appearance of stimuli and backgrounds (hue, chroma, and lightness), stimulus types (2D and 3D), and Background Patterns (contrast and non-contrast). Results revealed that background and stimulus appearance in AR environments exhibit effects similar to those in non-AR settings. However, the stimulus types and Background Patterns enhance visual cues related to layer perception, introducing additional complexity to lightness perception in AR. Furthermore, the study evaluated the performance of existing and AR-specific color appearance models (CAMs). Comparative analysis showed that the updated AR models outperformed existing CAMs in predictive accuracy, offering valuable insights into simultaneous lightness contrast in AR environments.

Eddie Pei, Susan Farnand, Michael J. Murdoch

Research Highlight: **Evaluation of Lightness Preference of Images on OLED and QLED Displays**

This research investigated the influence of lightness, lightness contrast, observer characteristics, and display types on image preference. Previous studies have emphasized the importance of color attributes in shaping image quality; in this study, we explored lightness attributes using CIECAM16 color space. Four experiments were conducted on OLED and QLED displays, during which participants selected their preferred images and rated their quality relative to a reference. The results indicated that lightness attributes significantly impact image preference across different display types. Furthermore, image preference varies notably among observers with different characteristics.

Eddie Pei, Hosub Lee, Elena Fedorovskaya,
Susan Farnand

Research Highlight: **Spectral Rendering and Application in Virtual Production**

Digitally rendered scenes are crucial for creating engaging entertainment experiences across various media formats, including video games, immersive art, and virtual production. One shortcut in typical approaches of rendering software is computing interactions of light and matter in RGB color spaces. As these three values represent light integrated by Color Matching Functions, spectral interactions of lights and materials in the virtual scene are not be properly computed and rendered. To address the mismatch between real on-set light and object interactions and simulated interactions, we investigate methods for approximating spectral rendering, which maintain efficiency and increase accuracy. Real-life interactions will be measured and simulated within a renderer, utilizing metrics such as ΔE and spectral differences to compare physical measurements with spectral rendering techniques and determine which methods yield more accurate results. This research aims to inspire current industry trends to shift toward a more color-accurate rendering solution.

Vlad Simion and David Long

Publication Highlight: **Munsell Trees**

M.D. Fairchild, ***Munsell Trees: A Season of Leaves and Colors***, RIT Press, Rochester, (2024).

Mark's beautiful new book presents photographs of transilluminated leaves from 24 different tree species that were collected through the entire 2021 growing season. Images are presented in collections by tree species, by date of collection, and simply by visual interest. Additionally, the leaves are presented within charts illustrating their Munsell color coordinates. Chapters in the book describe the sampling and photographic procedures, the history of the area the trees were found, the Munsell system of color order, and the inspiration of Henry David Thoreau for the entire project, which was completed during a recent sabbatical.

Mark Fairchild

RIT Press Link

Publications 2024

Journal Papers

E. Pei, S. Farnand and M.D. Fairchild, **Extending CIECAM16 to account for simultaneous contrast**, *Color Research and Application* **50**, in press (2024).

C. Shen and M.D. Fairchild, **Individual color matching functions from cross-media color-matching experiment**, *Color Research and Application* **50**, 10.1002/col.22960 early view (2024).

S. Abasi, L. Hellwig, D. Stolitzka and M.D. Fairchild, **Changes in displayed brightness/lightness with stimulus size**, *Journal of Imaging Science and Technology* **69**(2) 1-11 (2024).

C. A. Thorstenson and Y. Tian, **Dimensional approach for using color in social robot emotion communication**, *Color Research and Application* accepted (2024).

S. R. Herbeck, M. J. Murdoch, and C. A. Thorstenson, **Adjusting transparency toward optimizing face appearance in optical see-through augmented reality**, *Journal of Perceptual Imaging*, **7** (2024).

E. Pei, H. Lee, E. Fedorovskaya, S. Farnand, **Factors impacting human-perceived visual quality on television displays**, *Frontiers in Neuroscience*, **18**, 1426195 (2024).

S. Sreekantaswamy, M. Baghchechi, S. Siddiqui, J. Lester, S. Farnand, L. Zukley, K. Abuabara, **Comparison of Fitzpatrick Skin Type Methodologies and Photographic Skin Color Assessment**, *Journal of the American Academy of Dermatology,* submitted (2024)

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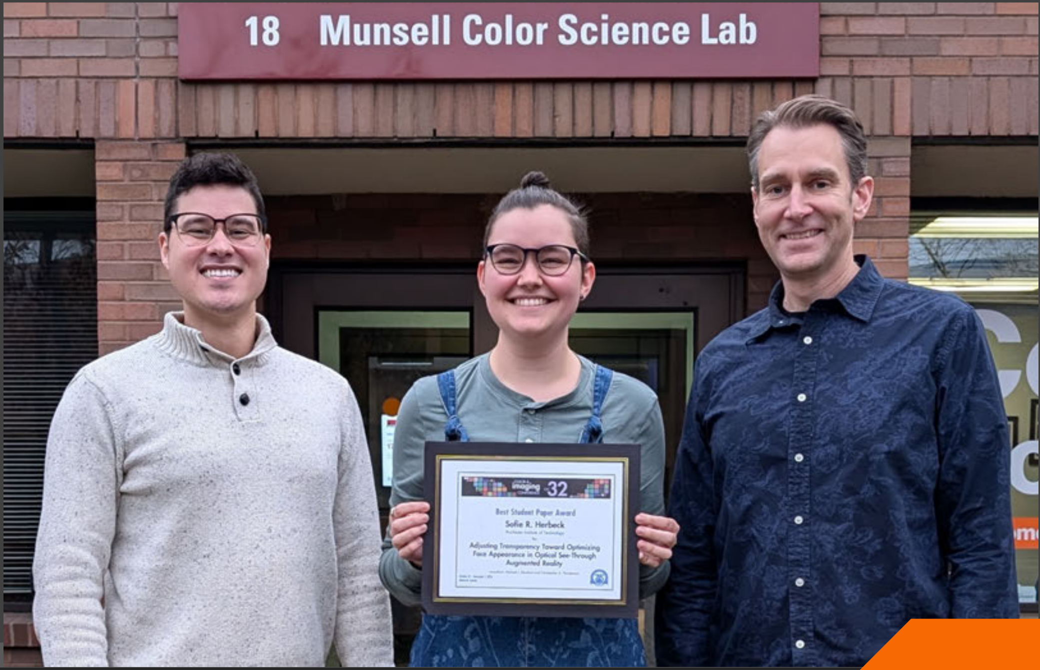


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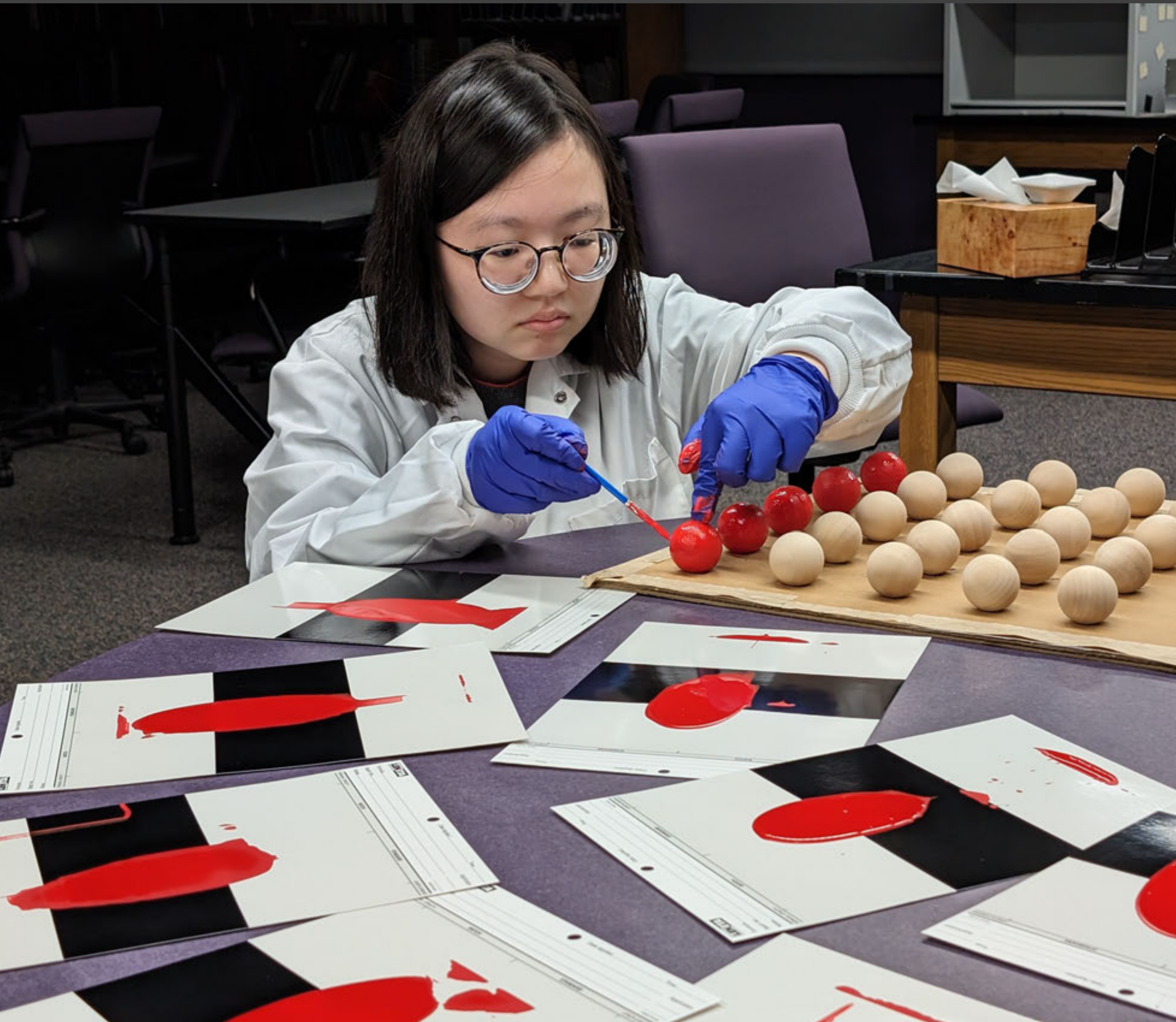

Publications 2024

Conference Proceedings

E. Pei, M. J. Murdoch & S. P. Farnand, **Connecting Individual Color Matching Functions to Accuracy and Preference in Image Reproduction**. *IS&T Color and Imaging Conference* (2024).

C. Shen and M.D. Fairchild, **Equalization of appearance using individualized unique hues**, *IS&T Electronic Imaging 2024,* 168-1 - 168-5 (2024).

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Other Presentations

Y. He and C. A. Thorstenson, **Poster: Facial color matching in optical see-through augmented reality**. *UR AR/VR Symposium*, Rochester, NY (2024).

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S. R. Herbeck, M. J. Murdoch, and C. A. Thorstenson, **Talk: Adjusting transparency toward optimizing face appearance in optical see-through augmented reality**. *32nd Annual Color and Imaging Conference*, Montreal, QC CA (2024).

Y. Tian, M. A. Abebe, and C. A. Thorstenson, **Talk: The influence of material roughness on perceived gloss and color appearance of graphical generated faces**. *32nd Annual Color and Imaging Conference*, Montreal, QC CA (2024).

S. R. Herbeck, M. J. Murdoch, and C. A. Thorstenson, **Talk: Perceptual transparency scaling in optical see-through AR**. *RIT Graduate Showcase*, Rochester, NY (2024).

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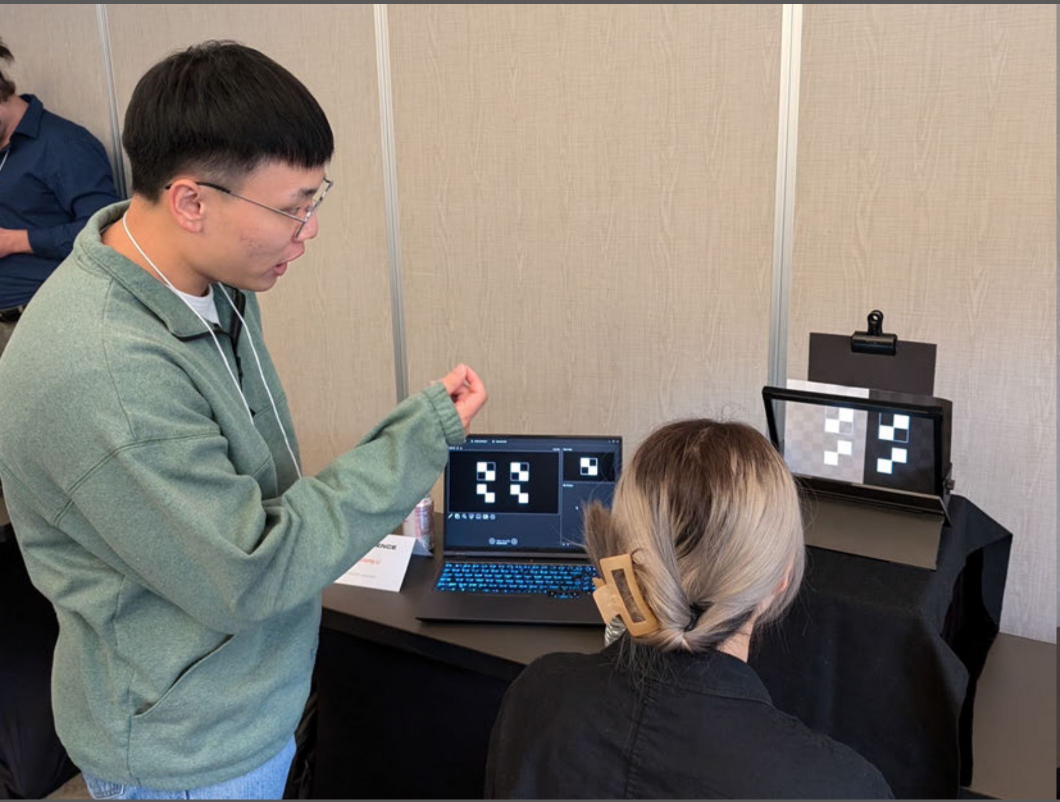

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Key
BS: Bachelor of Science
CS: Color Science
IE: Industrial Engineering
EE: Electrical Engineering
IPT: Imaging and Photo Technology
IS: Imaging Science
MS: Master of Science
PhD: Doctor of Philosophy
PM: Print Media
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