Remote Laboratory Activities for Color Science Education

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Abstract: Remote tutorials were designed and performed to demonstrate color appearance phenomena to students. Results suggest that remote lab demonstrations can provide an alternative to in-person lab sessions with caveats and offer additional benefits.

1. Background

Colorimetry is the science of color measurement, which provides tools to quantify and communicate the color quality of objects and light sources. Color science tools, mathematical models that estimate human color vision, are widely used in optical, architectural, and chemical engineering [1], and increasingly more used in other fields of science, such as dentistry [2] and food sciences [3]. Despite the computational nature of colorimetry, it is fundamentally a topic that requires visual demonstrations to teach color science fundamentals to students.

Color science education is often supported with the demonstration of color appearance phenomena, such as the simultaneous contrast, Hunt effect, Bezold-Brucke hue shift, Abney effect, Helmholtz-Kohlrausch effect, Helson-Judd effect [4]. These phenomena are the basis of color appearance models used in illumination engineering, photonics, and colorimetry. The demonstration of color appearance effects requires students to be immersed in an environment where the appearance of surfaces is altered by controlling light sources. Teachers can control spectral and spatial distribution and luminous output of a light source to achieve the intended effect under controlled conditions, such as a research or a teaching laboratory.

Unfortunately, due to the global outbreak of the Coronavirus disease 2019 (COVID-19), traditional classroom education has been interrupted worldwide. In response to the pandemic, e-learning and online laboratory demonstrations have gained recognition in science education [5,6]. Similar to other educational fields, color science requires teaching basic concepts to students to enhance their mastery of the subject matter, develop scientific reasoning abilities, understand the complexity and nature of science. To address the challenge of teaching color science concepts during the pandemic, a remote color tutorial has been designed and conducted in the Lighting Lab of the Department of Architectural Engineering at Pennsylvania State University. The online tutorials were part of a graduate course for higher-level undergraduate and graduate students.

2. Remote and In-Person Lab Tutorials

Two tutorials (for both in-person and remote portions) have been developed to demonstrate chromatic adaptation and the Hunt effect. Students were allowed to decide whether they want to take part in in-person and/or remote section of the demonstrations. Both demonstrations took place the week after the direct instruction of chromatic adaptation and color appearance phenomena.

In the in-person lab demonstrations, only two students were allowed at a time due to the university's COVID-19 policy. Students were trained to use the hue scaling test [7] via a short training using paper and pen and a set of color prints. Consequently, students sat down 2 m away from a white wall that was illuminated with a multi-primary LED light source that was controlled with software, as shown in Fig. 1. In the chromatic adaptation tutorial, students were asked to judge the appearance of a white disk on the wall under three adapting white lighting conditions and a green test light using the hue scaling test. In the following Hunt effect demonstration, students judged the perceived colorfulness of a test sample under five varying illumination levels using a magnitude estimation technique [8].

For the remote lab demonstrations, the same lighting routines for both color appearance phenomena were recorded using a high dynamic range (HDR) webcam. The high-resolution videos were uploaded to the Penn State e-learning site, along with marking sheets and step-by-step instructions on how to run the tutorials. The instruction included eliminating light sources, ensuring a two-meter distance from the display, adjusting display brightness and color settings, etc. Students viewed the videos at home and performed the same judgments using hue scaling and magnitude estimation techniques.

The results of the remote and in-person color science demonstrations were discussed in the following week's lecture. Chromatic adaptation results were similar as expected (students found the stimulus to be whiter after adapting two minutes), but stimuli in remote lab demonstrations were perceived more saturated than stimulus seen in the lab. The Hunt effect demonstrations were similar for high and low illumination levels, but students could not

Sixteenth Conference on Education and Training in Optics and Photonics: ETOP 2021,
edited by A. Danner, A. Poulin-Girard, N. Wong, Proc. of SPIE Vol. 12297, 122970B
© 2022 SPIE · 0277-786X · doi: 10.1117/12.2635512

identify the differences between the three lighting conditions in the middle when they were completing the remote lab demonstrations. The differences between demonstrations were due to the limited range of the webcam and the disparity in the adapting white conditions. The discussion of the results was followed by a Q&A session on the color appearance phenomena and the difference between color imaging and the human visual system.

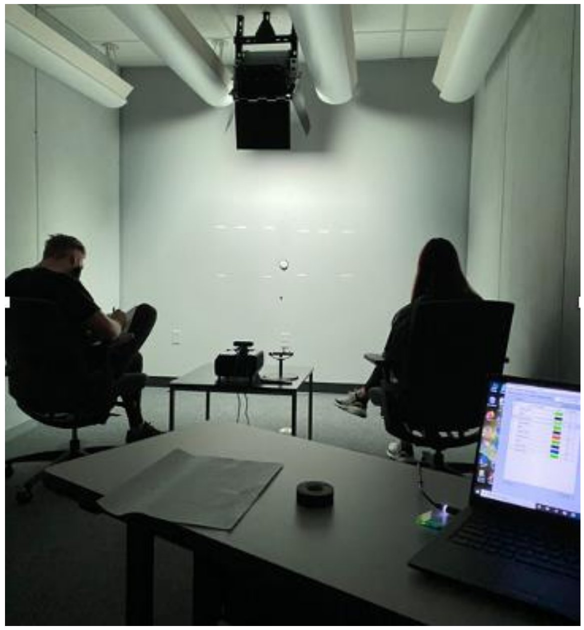

Fig. 1. Students participated to in-person color appearance demonstrations in the lab and later completed assignments of the same color demonstrations at home.

3. Conclusions

Immersive visual demonstrations are a key part of color science education. In the absence of in-person tutorials, remote laboratory demonstrations can provide an alternative. Results of the in-person and remote color appearance tutorials indicate that a pleasant and productive learning opportunity can be created via remote laboratory demonstrations. Despite the limitation of the remote laboratory tutorials (i.e., weaker results and technology dependence), results were encouraging. A relatively low-budget tutorial can be designed so that students can participate in the comfort of their homes.

The remote lab demonstrations can also provide a way to highlight the difference between the human visual system and electronic imaging systems (e.g., cameras, displays). Although the human eye is often considered analogous to a digital camera, there are important differences between the two – most notably the dynamic nature of the visual system.

4. References

[1] G. Wyszecki and W. S. Stiles, *Color science*. (Wiley, 1982), Vol. 8.

[2] S. Westland, "Review of the CIE system of colorimetry and its use in dentistry," Journal of Esthetic and Restorative Dentistry **15**, S5-S12 (2003).

[3] J. L. Caivano and M. del Pilar Buera, *Color in food: technological and psychophysical aspects* (CRC Press, 2012).

[4] M. D. Fairchild, *Color appearance models* (John Wiley & Sons, 2013).

[5] S. Ray, S. Srivastava, "Virtualization of science education: a lesson from the COVID-19 pandemic," J. Proteins Proteomics, 11, 77-80 (2020).

[6] M. Youssef, E. L. McKinstry, A. Dunne, A. Bitton, A. G. Brady, and T. Jordan, "Developing Engaging Remote Laboratory Activities for a Nonmajors Chemistry Course During COVID-19," Journal of Chemical Education **97**(9), 3048-3054 (2020).

[7] J. Gordon, I. Abramov, and H. Chan, "Describing color appearance: Hue and saturation scaling," Perception & psychophysics **56**(1), 27-41 (1994).

[8] E. C. Poulton, "The new psychophysics: six models for magnitude estimation," Psychological bulletin **69**(1), 1 (1968).