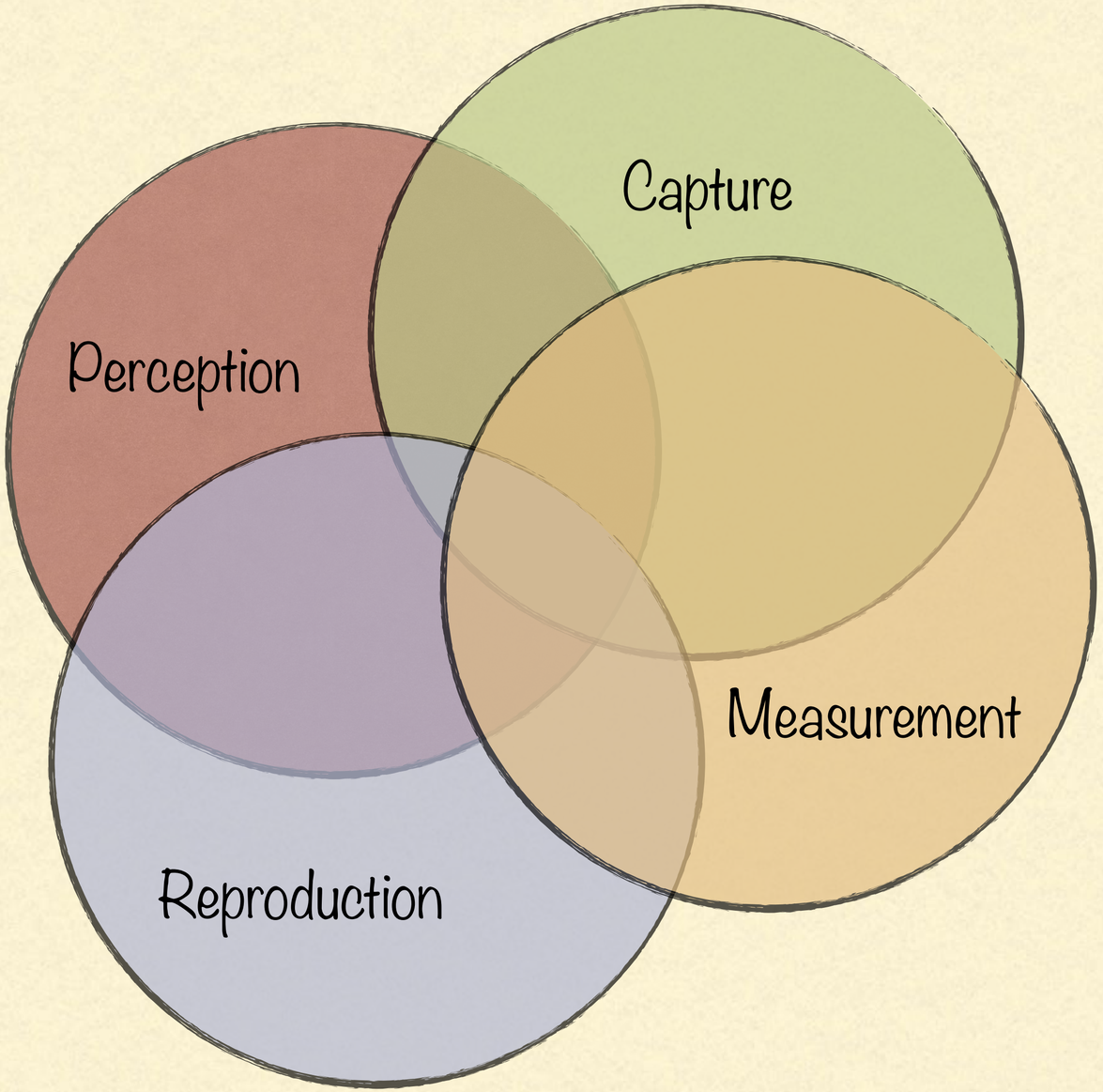
UNDERWATER COLORIMETRY

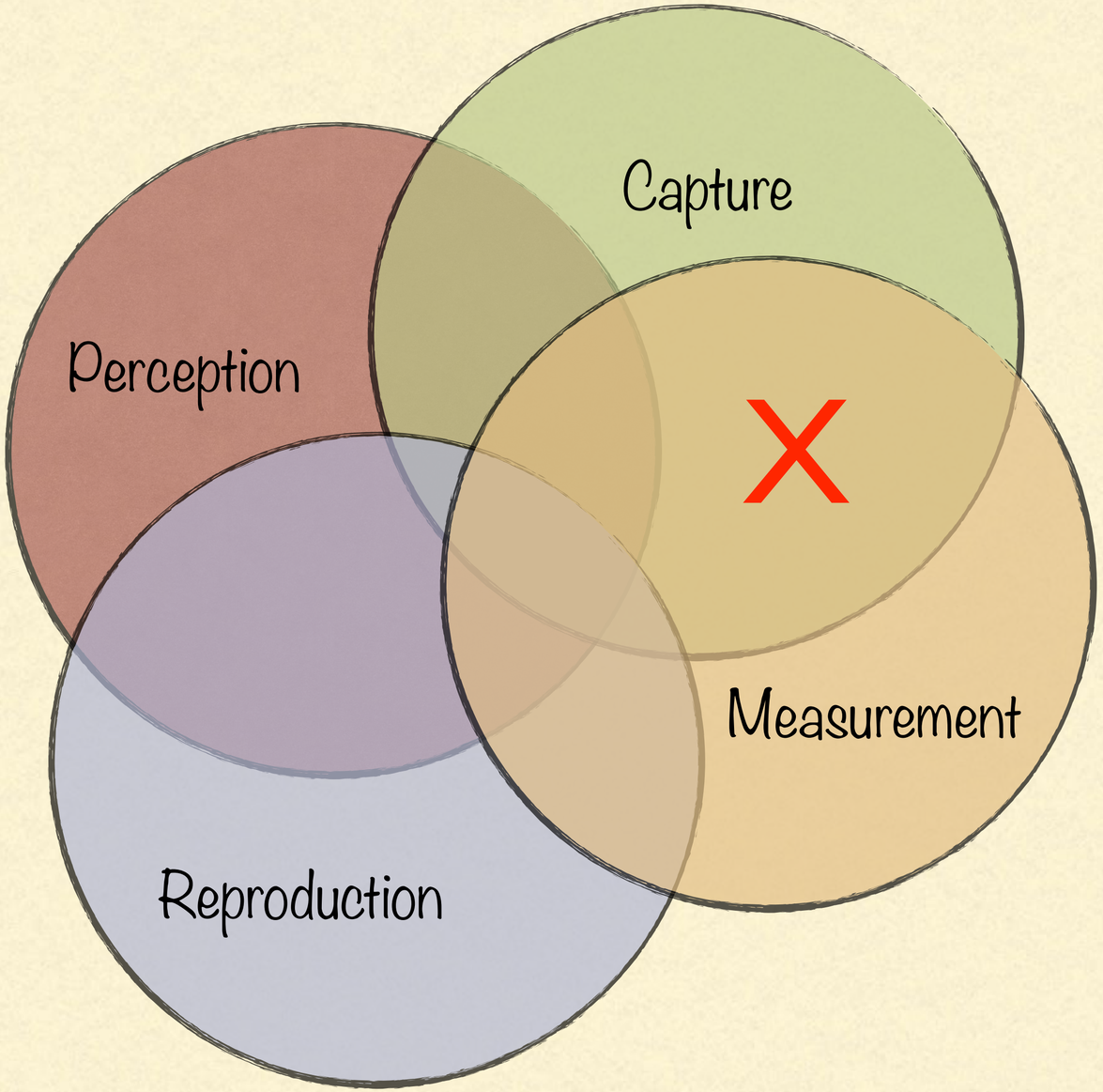
INTRODUCTION

COLOR PERCEPTION

Dr. Derya Akkaynak | dakkaynak@univ.haifa.ac.il



Color Is Complex

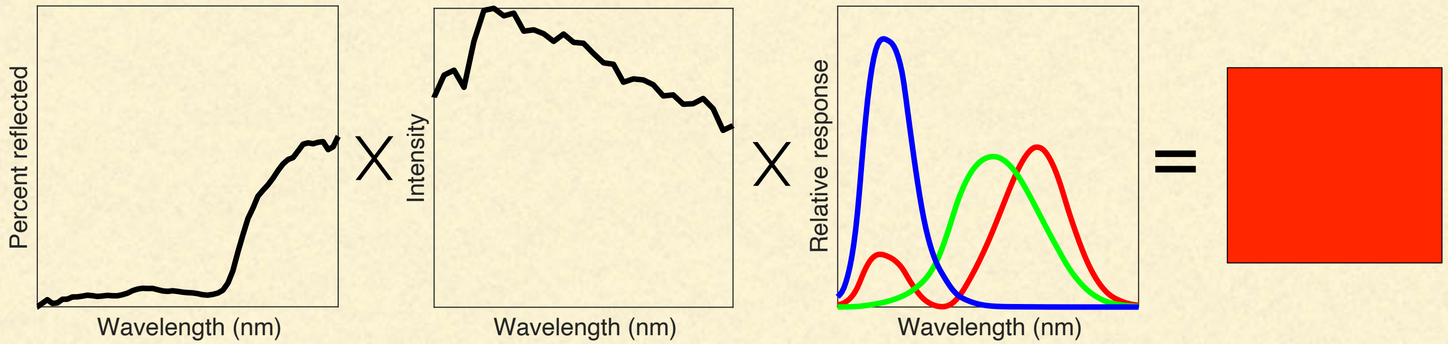


Color Is Complex

Color Perception

Color is a subjective phenomenon

Reflectance Light Observer Color



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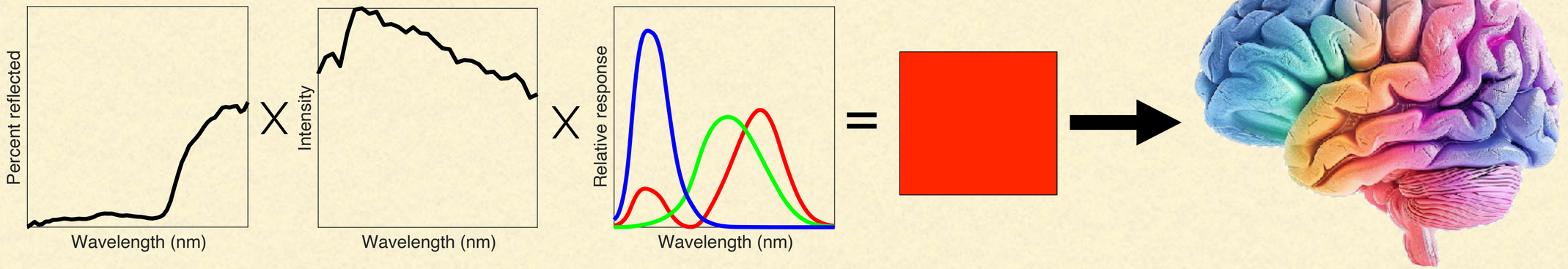
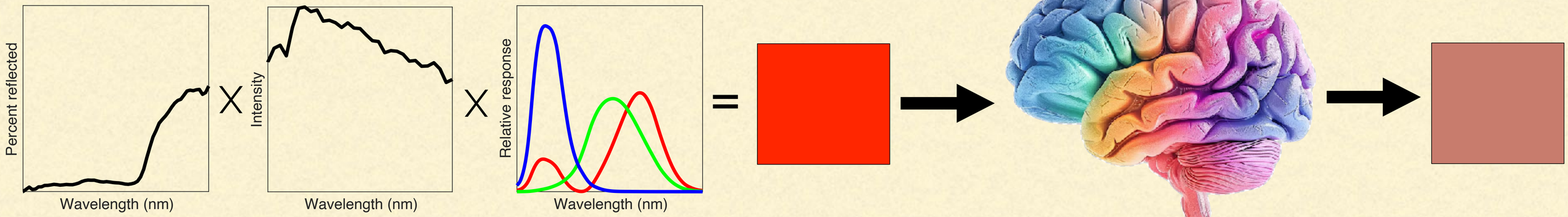


Color Perception

Color is a subjective phenomenon

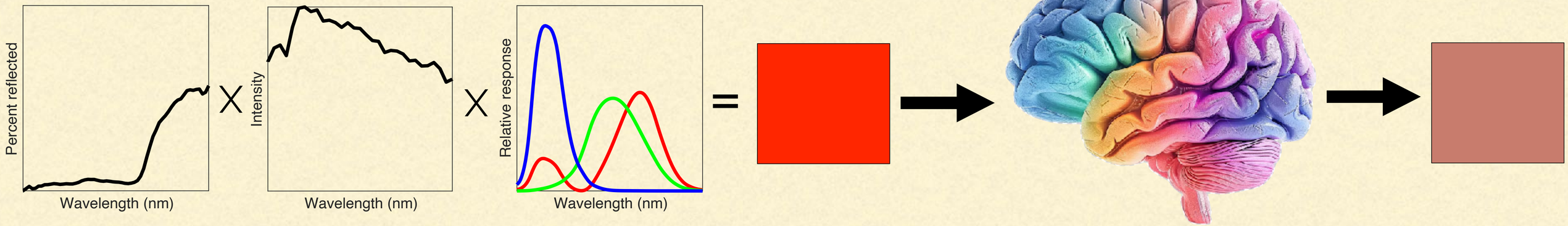
Reflectance | Light | Observer | Color



Color Perception

Color is a subjective phenomenon

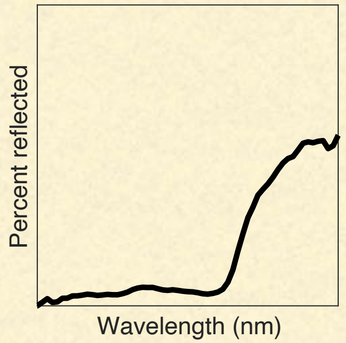
Reflectance | Light | Observer | Physical Color



Color Perception

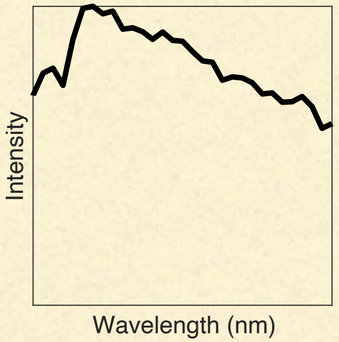
Color is a subjective phenomenon

Reflectance



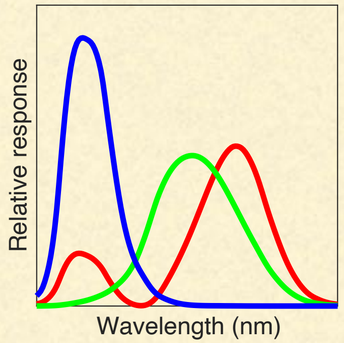
X

Light



X

Observer



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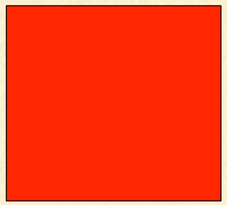
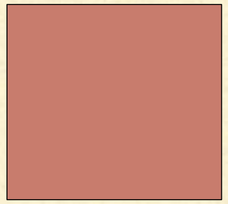
Physical Color



Perceived Color



Who Is the Observer?

Color is a subjective phenomenon

Who Is the Observer?

Color is a subjective phenomenon

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PLOS BIOLOGY

2024

METHODS AND RESOURCES

Recording animal-view videos of the natural world using a novel camera system and software package

Vera Vasas[1]*, Mark C. Lowell[2,3], Juliana Villa[3], Quentin D. Jamison[3], Anna G. Siegle[3], Pavan Kumar Reddy Katta[4], Pushyami Bhagavathula[4], Peter G. Kevan[5], Drew Fulton[6], Neil Losin[7], David Kepplinger[8], Michael K. Yetzbacher[9], Shakiba Salehian[3], Rebecca E. Forkner[3], Daniel Hanley[3]*

Abstract

Plants, animals, and fungi display a rich tapestry of colors. Animals, in particular, use colors in dynamic displays performed in spatially complex environments. Although current approaches for studying colors are objective and repeatable, they miss the temporal variation of color signals entirely. Here, we introduce hardware and software that provide ecologists and filmmakers the ability to accurately record animal-perceived colors in motion. Specifically, our Python codes transform photos or videos into perceivable units (quantum catches) for animals of known photoreceptor sensitivity. The plans and codes necessary for end-users to capture animal-view videos are all open source and publicly available to encourage continual community development. The camera system and the associated software package will allow ecologists to investigate how animals use colors in dynamic behavioral displays, the ways natural illumination alters perceived colors, and other questions that remained unaddressed until now due to a lack of suitable tools. Finally, it provides scientists and filmmakers with a new, empirically grounded approach for depicting the perceptual worlds of nonhuman animals.

https://www.youtube.com/watch?v=9x4_552Lff0

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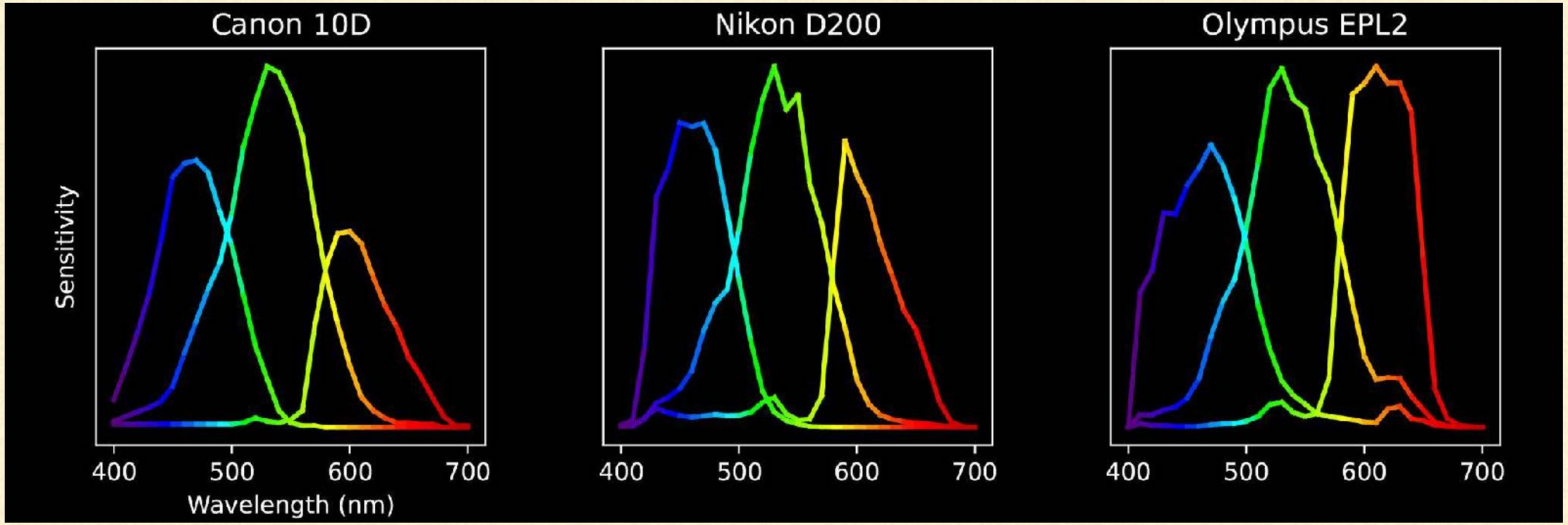
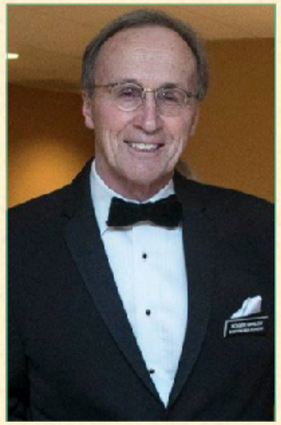
Who Is the Observer?

Every camera records colors differently.



Rapid Adaptive Camouflage



Prof. Roger Hanlon

(my PhD co-advisor)

https://www.youtube.com/watch?v=8CLKyMFHSfg

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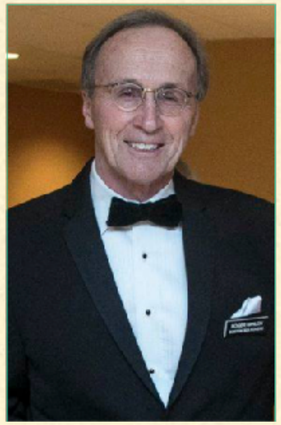

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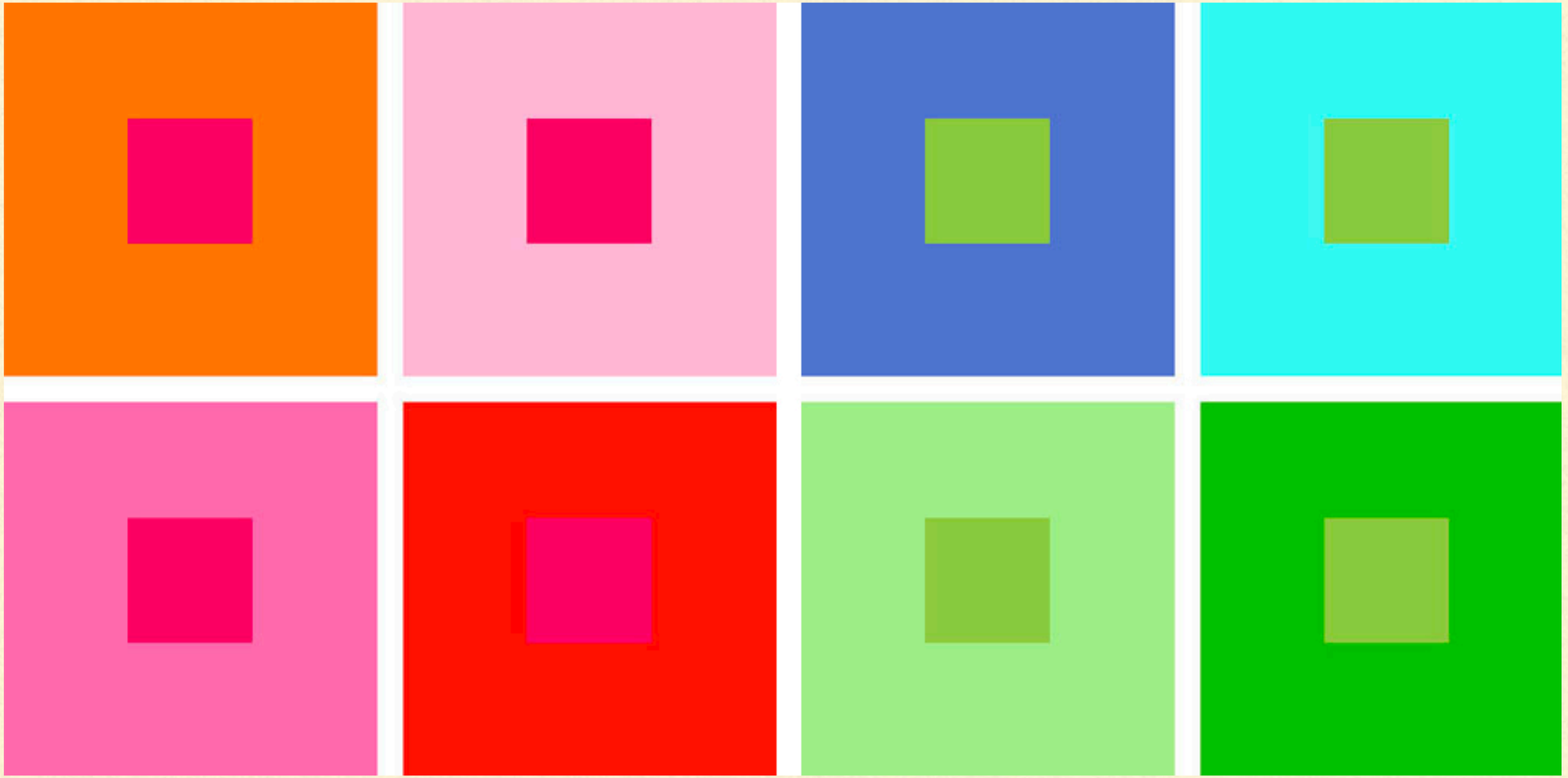
Perception of one color is influenced by the other colors around it: "simultaneous color contrast".



Color Perception

Color is only meaningful under a given light.

#thedress

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Color Constancy

Color constancy is the human visual system's ability to perceive colors consistently under varying light conditions.

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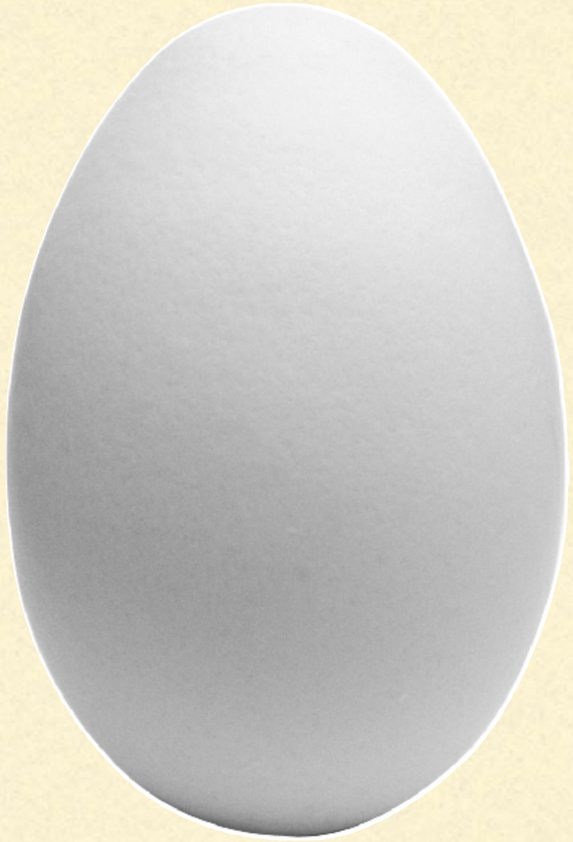

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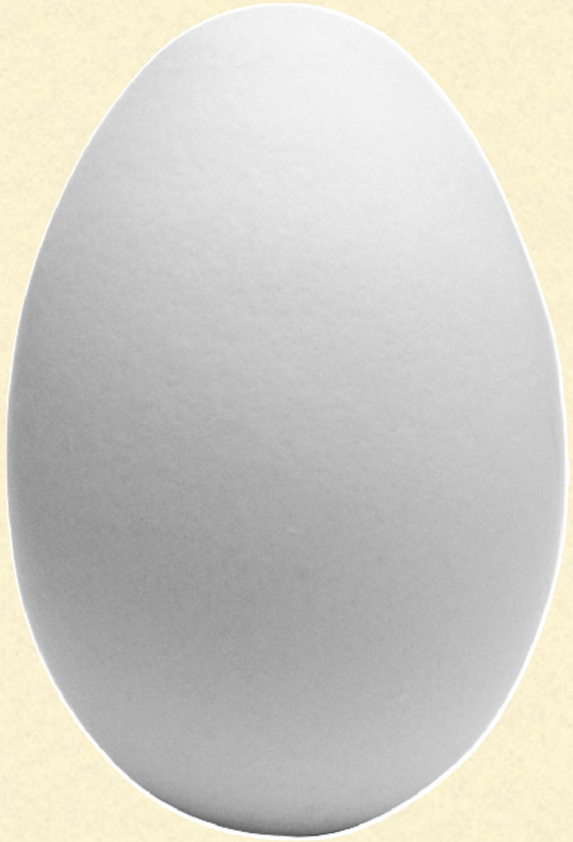

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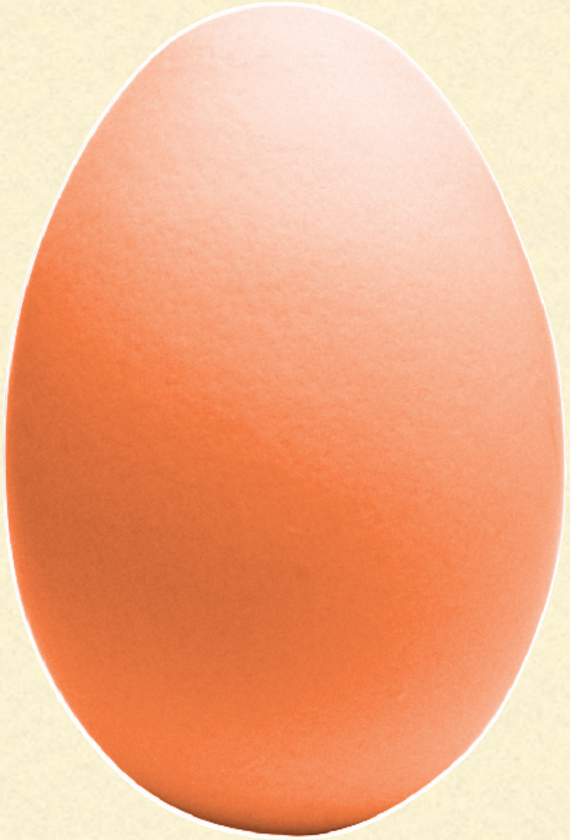

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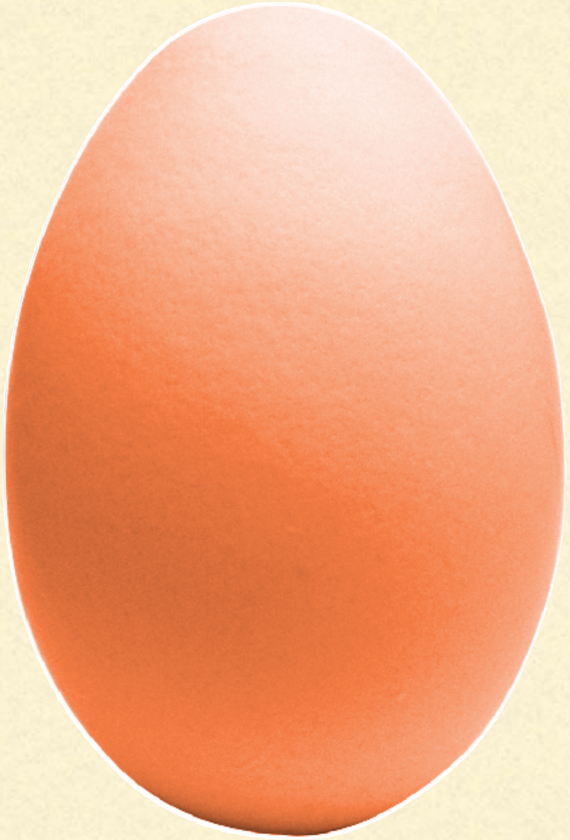

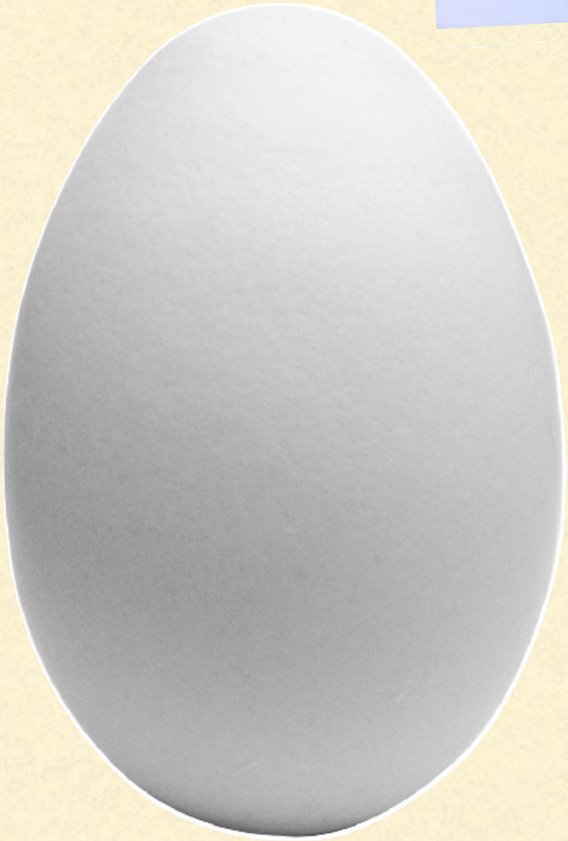

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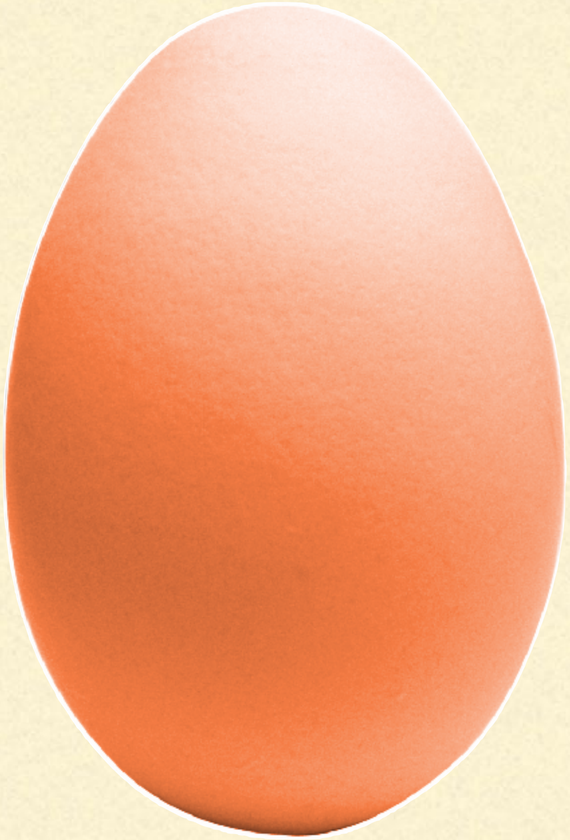

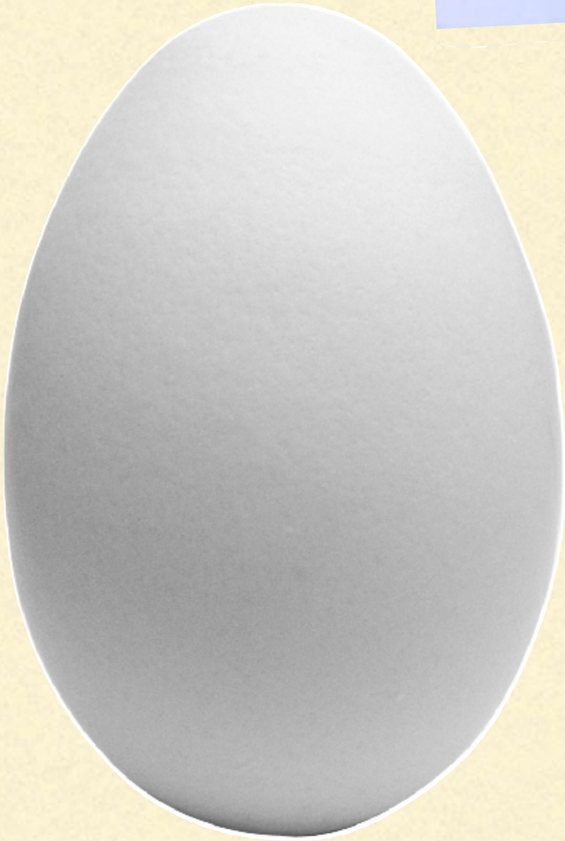

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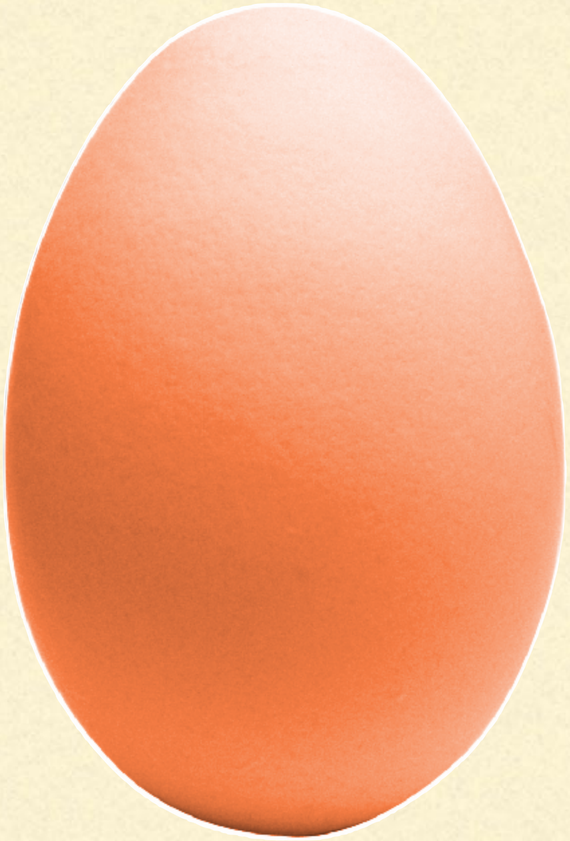
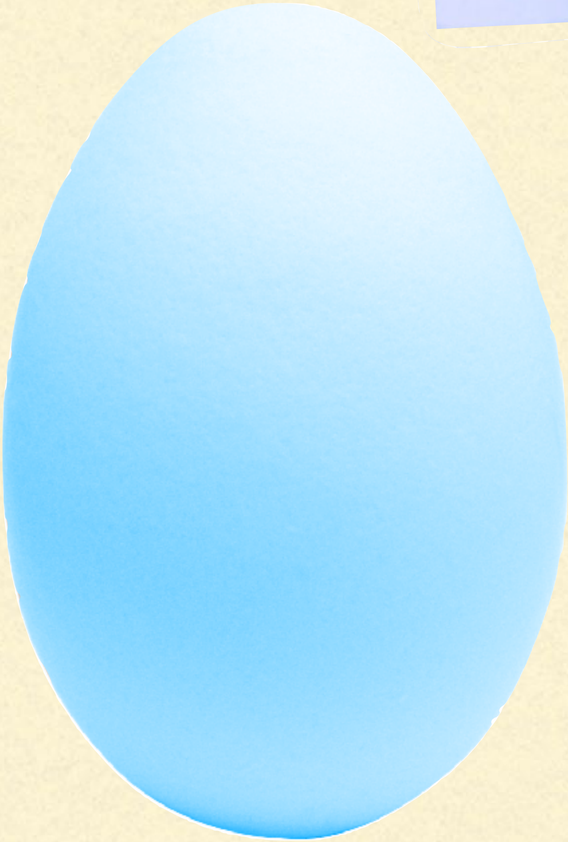
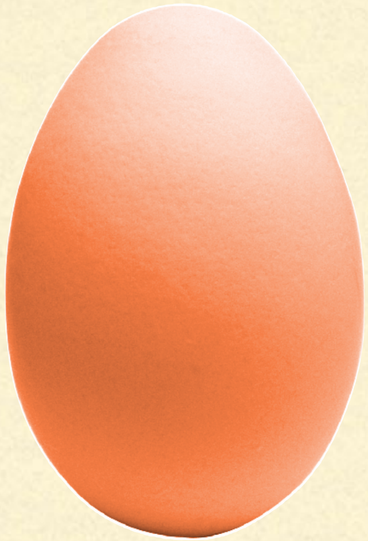
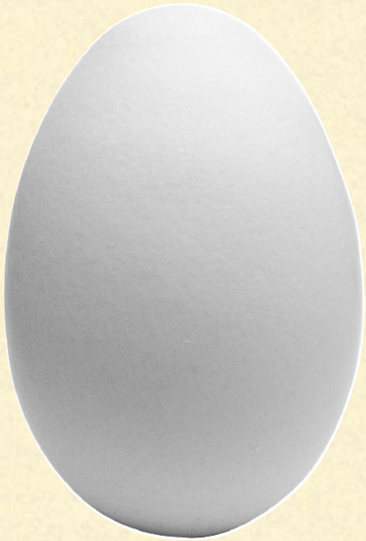




Color Constancy

Color constancy is surprisingly important for underwater computer vision.





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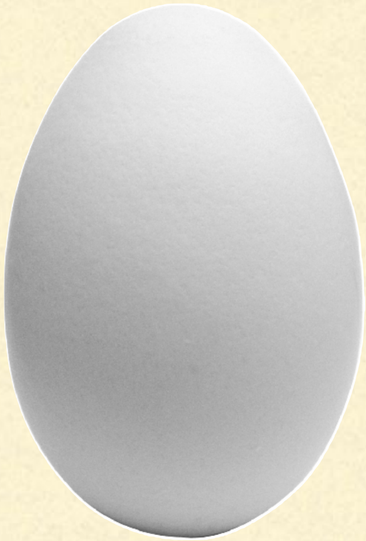

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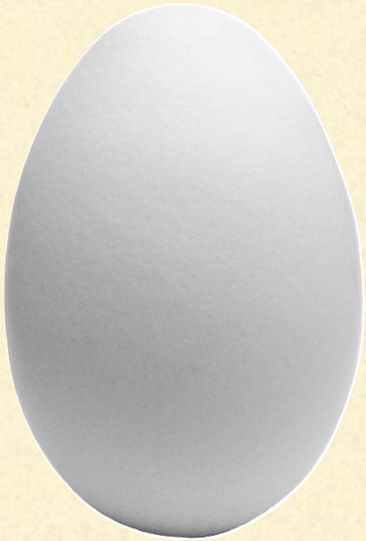

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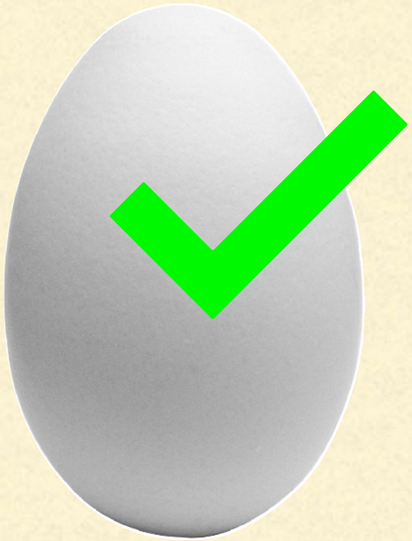

The Dress - WHY?

Color is only meaningful under a given light.

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https://youtu.be/-LKq4ZIDa_U?

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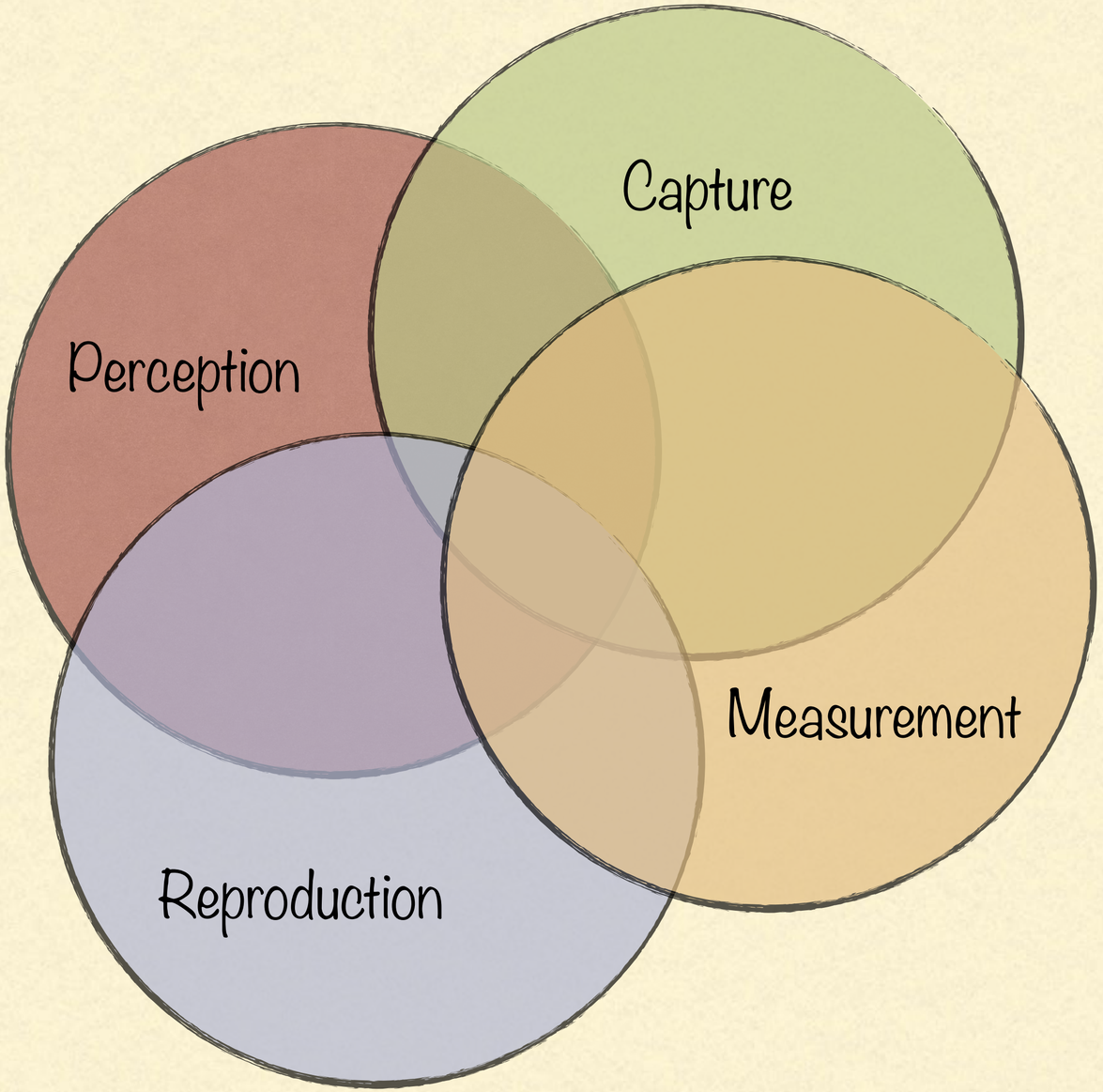
Color Perception

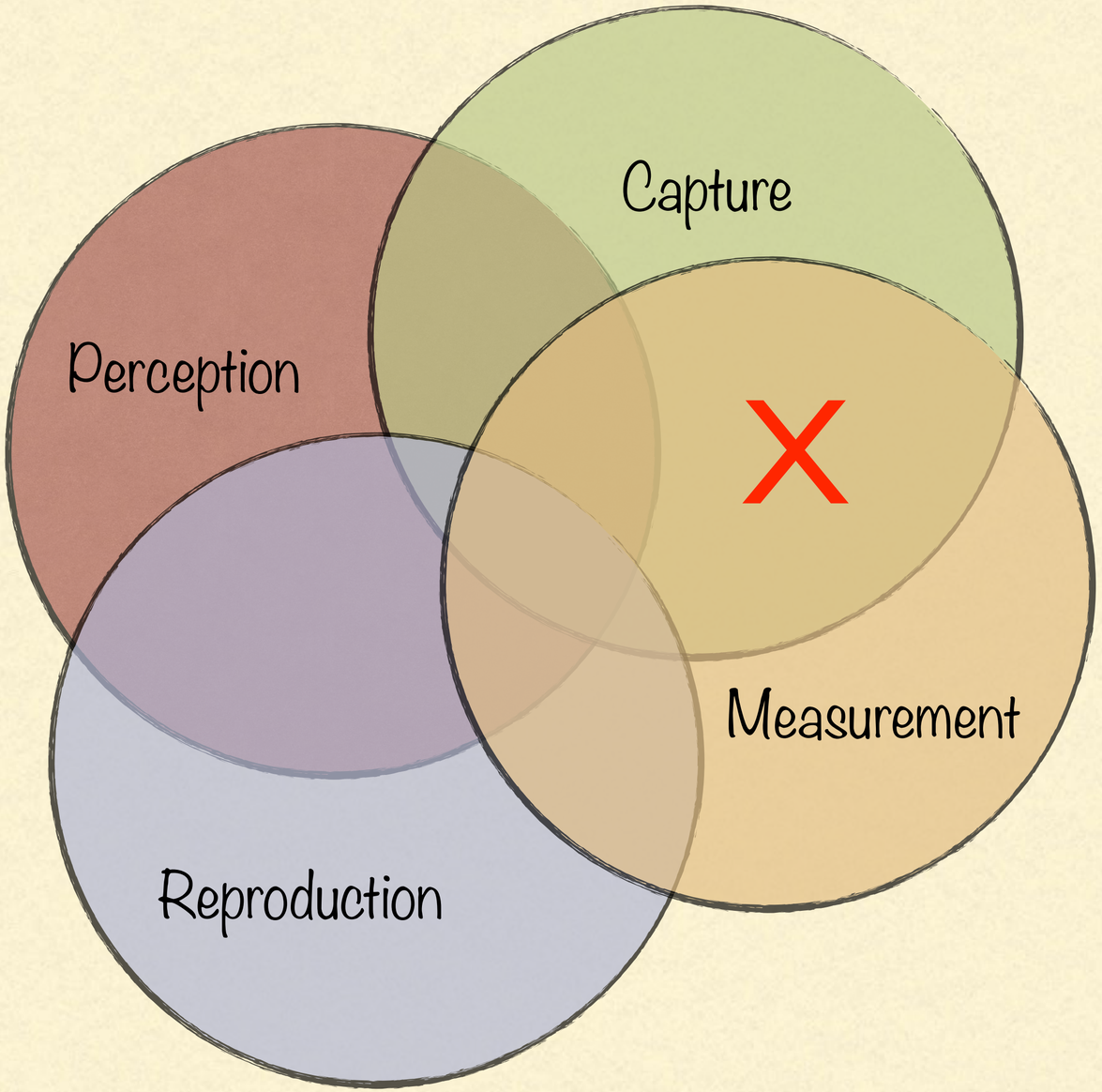
Human color perception changes with seasons.

Images from: Webster, Michael A., Yoko Mizokami, and Shernaaz M. Webster. "Seasonal variations in the color statistics of natural images." Network: Computation in neural systems 18.3 (2007)
Also see: Welbourne, Lauren E., Antony B. Morland, and Alex R. Wade. "Human colour perception changes between seasons." Current Biology 25.15 (2015)



Color Is Complex

+ **Subjective**



Color Is Complex

+ **Subjective**

HOW CAN WE MEASURE

A SUBJECTIVE QUANTITY

OBJECTIVELY?

COLORIMETRY

Is the science of measuring colors.

Where in life (and research) does it come handy to measure colors?

Color Theory

- Colorimetry
- Uniform/expanded color spaces
- Color gamuts
- Models of color perception
- Mathematical models of color
- Color appearance models

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Illumination & Lighting

- Physics & optics
- Color rendering
- Color mixing
- Light projection
- Illuminant metamerism
- Multi-illumination imaging
- Quality of light
- Psychology/human factors

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Color Vision & Cognition

- Visual adaptation
- Visual psychophysics
- Color vision deficiency
- Individual differences
- Salience and attention
- Psychological effects of color
- Spatial/temporal color vision
- Color constancy
- Metamerism
- Color semiotics
- Color language
- Color harmony
- Memory color
- Visual ecology

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Capture and Reproduction

- Image capture (360°, sensing, multi-modal)
- Multi-primary displays
- Display technologies
- Mobile color imaging
- White balancing
- Computational photography
- Color printing (multi-ink, special effects,…)
- High dynamic range (HDR)
- Pseudo-color and data visualization
- Color 3D printing
- Color workflows
- Paints/dyes/pigments
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Image Quality

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- Color gamut mapping
- Computational imaging/ computer vision
- Color difference metrics
- Color preference
- Color fidelity

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Computer Vision

- Image enhancement/restoration
- Scene understanding
- Object detection and identification
- Color-based or -assisted segmentation
- Color-based navigation/driving/robotics
- Defect inspection
- Industrial inspection
- Photometric stereo
- Neural radiance fields
- Gaussian splatting/volumetric rendering
- Shape from color
- Color transform, colorization
- Image relighting
- Bio-Medical imaging
- Agriculture/food analysis
- Surveillance/security
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Computer Graphics

- AR/VR/MR/CGI, video games
- Efficient coding of color spaces
- Color-based throughput optimizations
- Rending for variable environments or viewing conditions
- Color transfer
- Image relighting

Image Quality

- Color image processing
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- Gaussian splatting/volumetric rendering
- Shape from color
- Color transform, colorization
- Image relighting
- Bio-Medical imaging
- Agriculture/food analysis
- Surveillance/security
- Forensics
- Remote sensing

Computer Graphics

- AR/VR/MR/CGI, video games
- Efficient coding of color spaces
- Color-based throughput optimizations
- Rending for variable environments or viewing conditions
- Color transfer
- Image relighting

Multispectral Imaging

- Spectral image capture, quality, visualization
- Spectral displays and reproduction
- Animal vision
- Camouflage breaking

Image Quality

- Color image processing
- Color gamut mapping
- Computational imaging/ computer vision
- Color difference metrics
- Color preference
- Color fidelity

Color Theory

- Colorimetry
- Uniform/expanded color spaces
- Color gamuts
- Models of color perception
- Mathematical models of color
- Color appearance models

Illumination & Lighting

- Physics & optics
- Color rendering
- Color mixing
- Light projection
- Illuminant metamerism
- Multi-illumination imaging
- Quality of light
- Psychology/human factors

Color Vision & Cognition

- Visual adaptation
- Visual psychophysics
- Color vision deficiency
- Individual differences
- Salience and attention
- Psychological effects of color
- Spatial/temporal color vision
- Color constancy
- Metamerism
- Color semiotics
- Color language
- Color harmony
- Memory color
- Visual ecology

Capture and Reproduction

- Image capture (360°, sensing, multi-modal)
- Multi-primary displays
- Display technologies
- Mobile color imaging
- White balancing
- Computational photography
- Color printing (multi-ink, special effects,…)
- High dynamic range (HDR)
- Pseudo-color and data visualization
- Color 3D printing
- Color workflows
- Paints/dyes/pigments
- Nano-materials

Computer Vision

- Image enhancement/restoration
- Scene understanding
- Object detection and identification
- Color-based or -assisted segmentation
- Color-based navigation/driving/robotics
- Defect inspection
- Industrial inspection
- Photometric stereo
- Neural radiance fields
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- Color difference metrics
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Materials and Color Appearance

- Material appearance capture, reproduction, modeling (gloss, translucence,…)
- Color appearance models (CAMs)
- 3D (printing, CAD modeling, scanning)
- Spatial color models
- Computer generated imagery (CGI)

Color Theory

- Colorimetry
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- Surveillance/security
- Forensics
- Remote sensing

Arts

- Film/cinema/photography
- Architecture
- Broadcast video
- Cultural heritage applications

Computer Graphics

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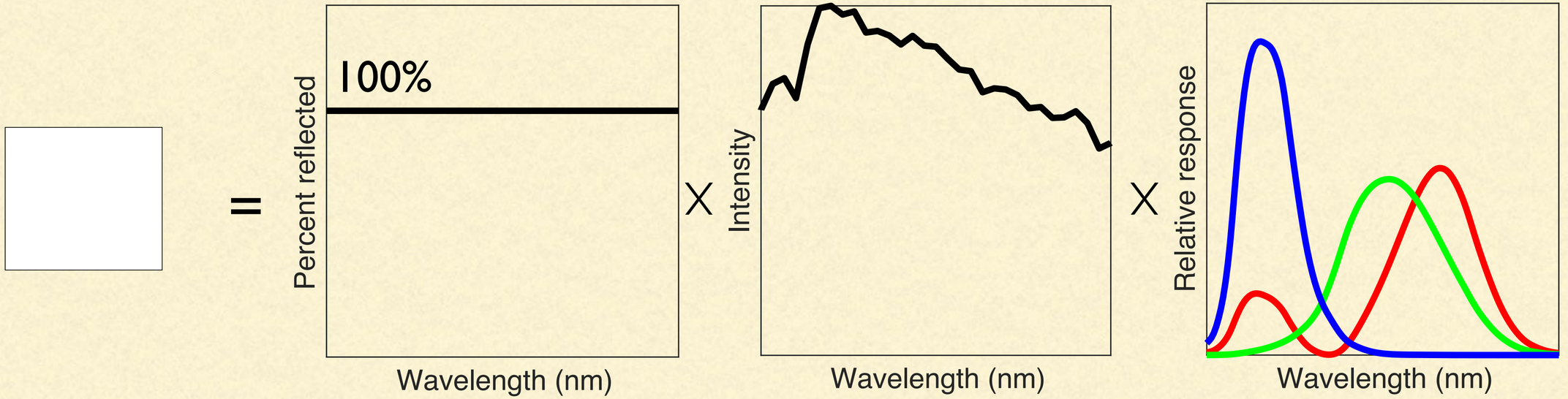
- Computer generated imagery (CGI)

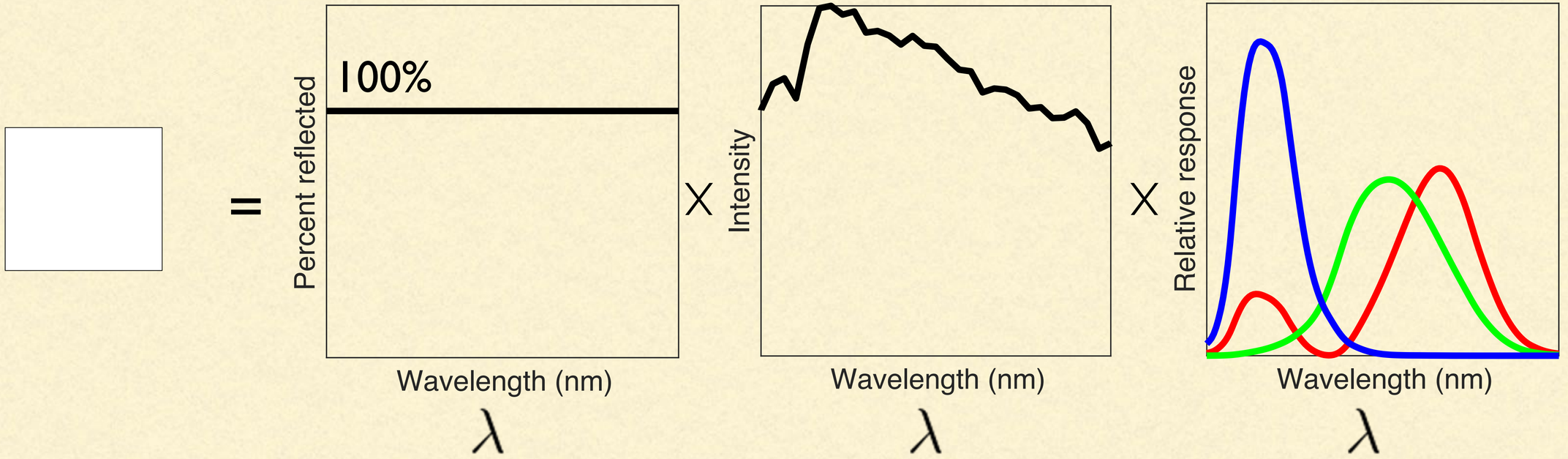
Color in Clear Air

Color = Reflectance X Light X Observer



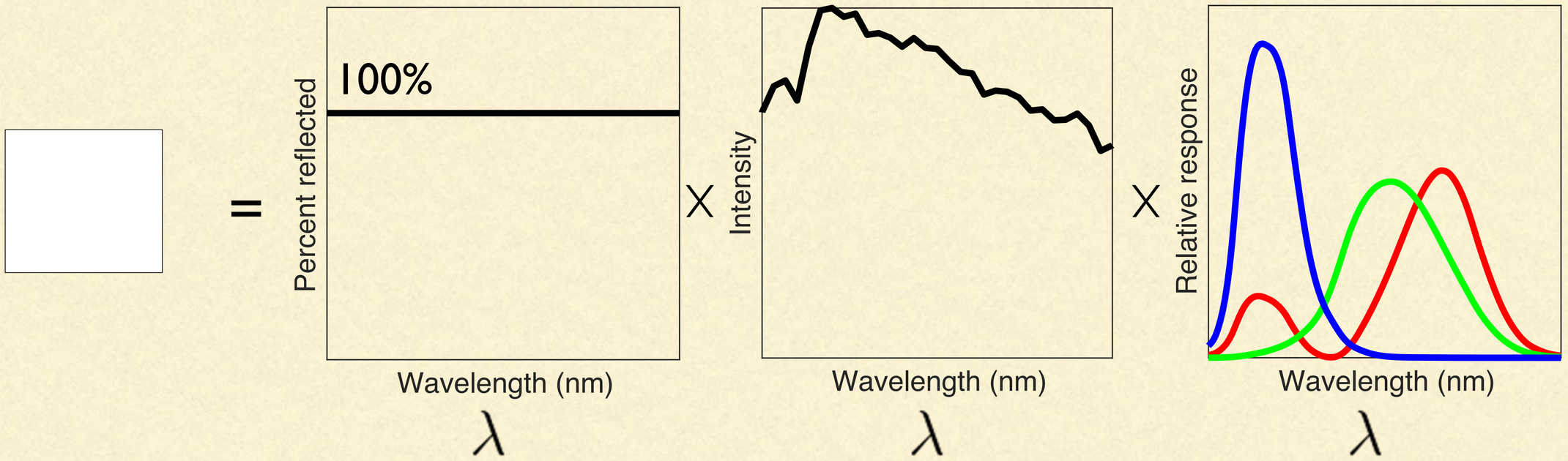
Color in Clear Air

Color = Reflectance X Light X Observer



Color in Clear Air

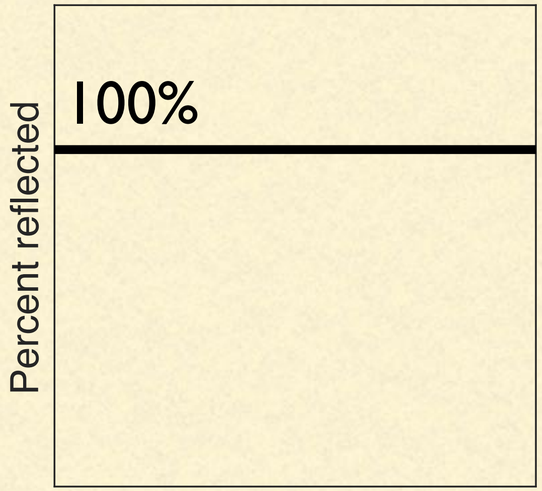
Color = Reflectance $\rho(\lambda)$ × Light × Observer



Color in Clear Air

Color = Reflectance $\rho(\lambda)$ × Light $E(\lambda)$ × Observer

=



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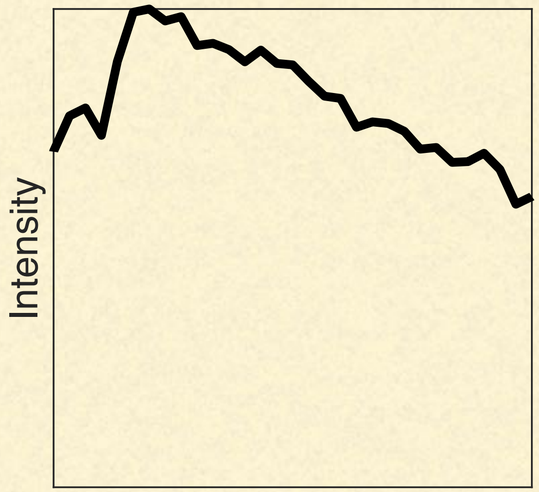

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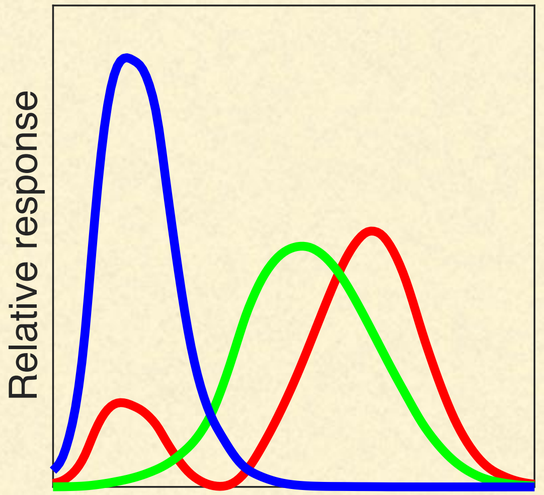
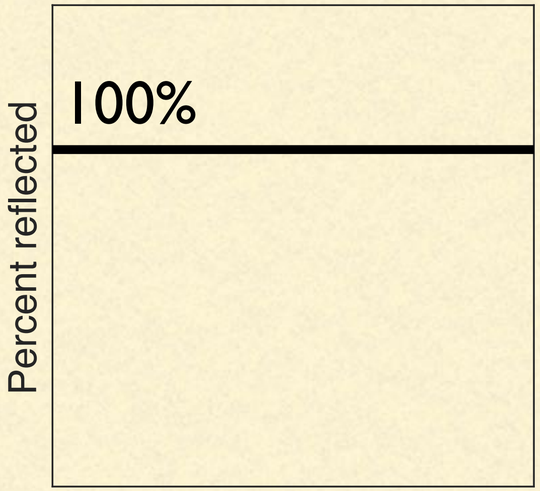


Color in Clear Air

Color = Reflectance $\rho(\lambda)$ × Light $E(\lambda)$ × Observer $S(\lambda)$

=



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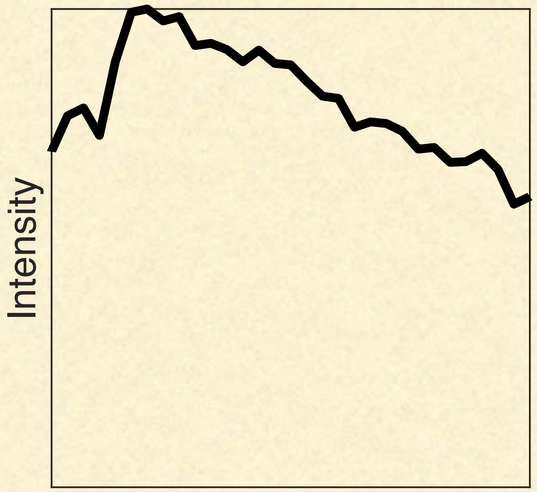

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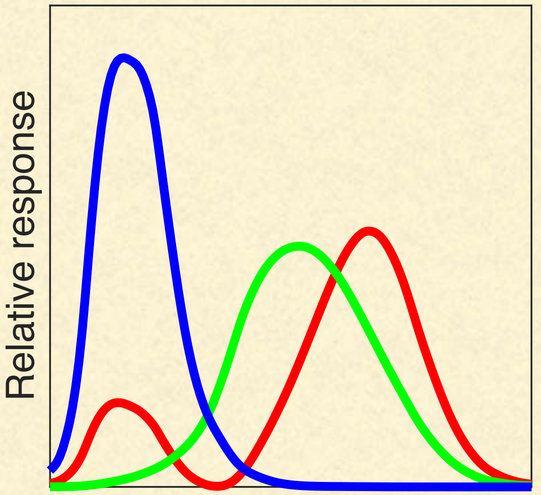


Color in Clear Air

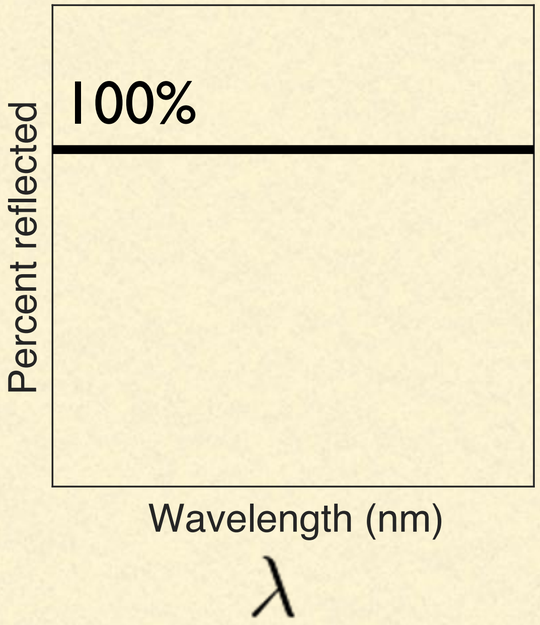
Color = Reflectance × Light × Observer

Reflectance $\rho(\lambda)$

Light $E(\lambda)$

Observer $S(\lambda)$

=



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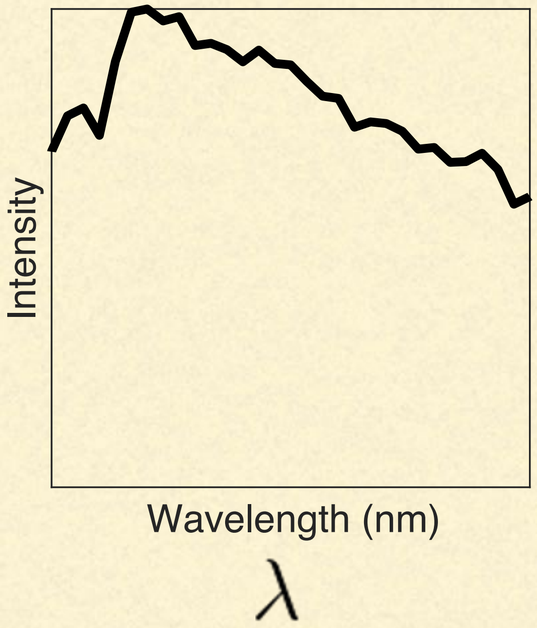

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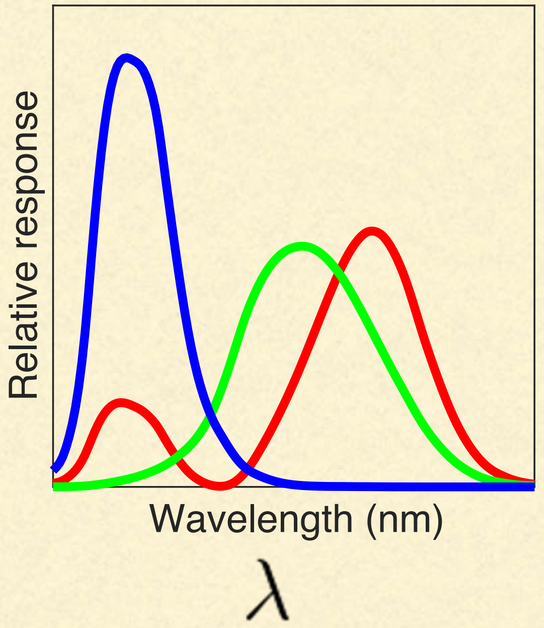


$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)d\lambda$$

κ: exposure-related constant

Color in Clear Air

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)d\lambda$$

Color in Clear Air

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)d\lambda$$

Color Underwater

Color in Clear Air

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)d\lambda$$

Color Underwater

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)$$

Color in Clear Air

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)d\lambda$$

Color Underwater

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)$$

Color in Clear Air

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)d\lambda$$

Color Underwater

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)e^{-K_d(\lambda)d}$$

Color in Clear Air

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)d\lambda$$

Color Underwater

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)e^{-K_d(\lambda)d}e^{-c(\lambda)z}$$

Color in Clear Air

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)d\lambda$$

Color Underwater

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)e^{-K_d(\lambda)d_e - c(\lambda)z}$$

+

Color in Clear Air

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)d\lambda$$

Color Underwater

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)e^{-K_d(\lambda)d}e^{-c(\lambda)z}$$

$$+ \quad \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \frac{b(\lambda)E(\lambda)e^{-K_d(\lambda)d}}{c(\lambda)}$$

Color in Clear Air

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)d\lambda$$

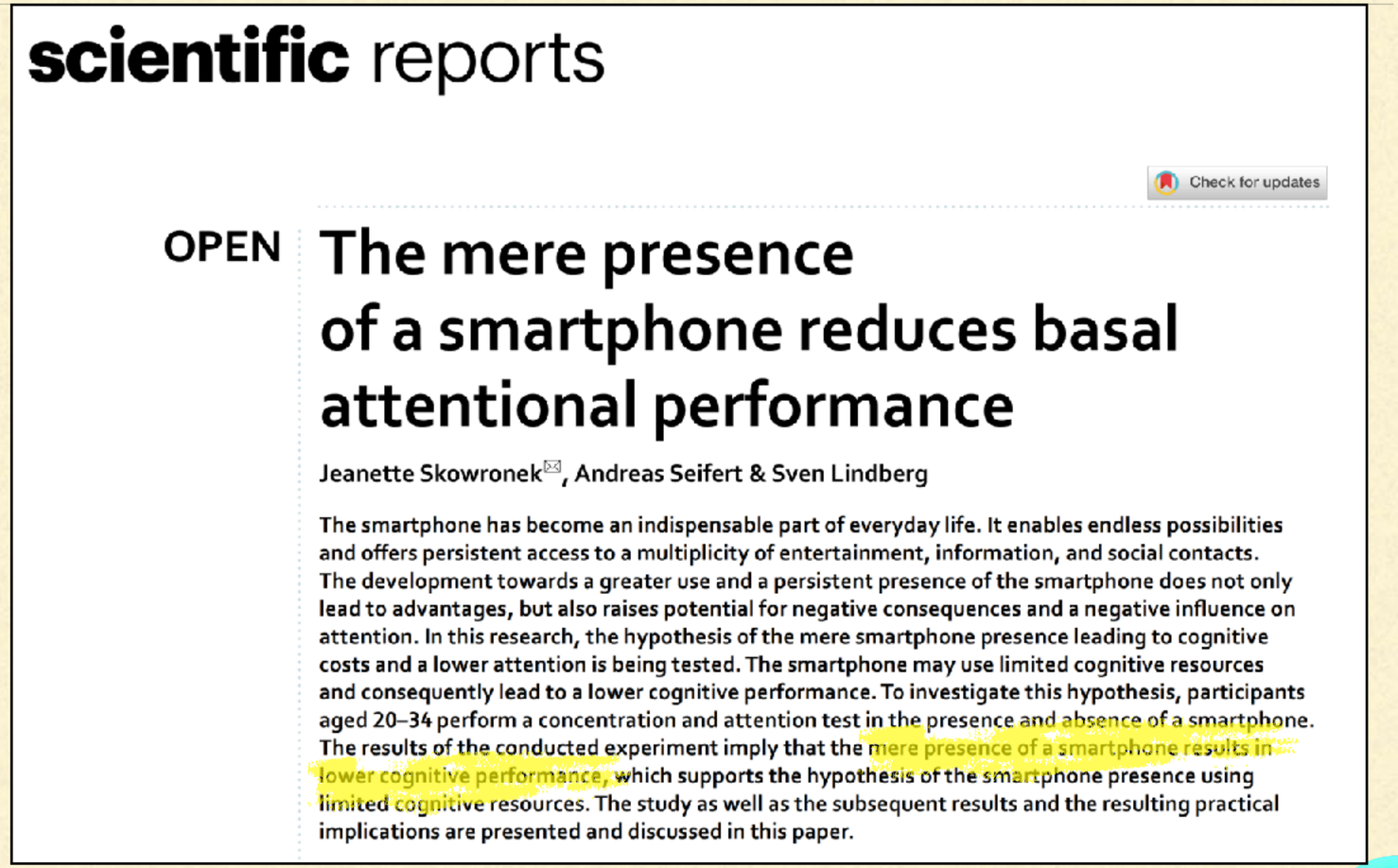
Color Underwater

$$Color = \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \rho(\lambda)E(\lambda)S(\lambda)e^{-K_d(\lambda)d}e^{-c(\lambda)z}$$

$$+ \quad \frac{1}{\kappa}\int_{\lambda_1}^{\lambda_2} \frac{b(\lambda)E(\lambda)e^{-K_d(\lambda)d}}{c(\lambda)}S(\lambda)(1-e^{-c(\lambda)z})d\lambda$$

Break

- Thank you for not using your cell phones during the lectures.
- PRO TIP: Disable all notifications. Give your attention to the phone only when you want, not when the phone wants.



scientific reports

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OPEN

The mere presence of a smartphone reduces basal attentional performance

Jeanette Skowronek✉, Andreas Seifert & Sven Lindberg

The smartphone has become an indispensable part of everyday life. It enables endless possibilities and offers persistent access to a multiplicity of entertainment, information, and social contacts. The development towards a greater use and a persistent presence of the smartphone does not only lead to advantages, but also raises potential for negative consequences and a negative influence on attention. In this research, the hypothesis of the mere smartphone presence leading to cognitive costs and a lower attention is being tested. The smartphone may use limited cognitive resources and consequently lead to a lower cognitive performance. To investigate this hypothesis, participants aged 20–34 perform a concentration and attention test in the presence and absence of a smartphone. The results of the conducted experiment imply that the mere presence of a smartphone results in lower cognitive performance, which supports the hypothesis of the smartphone presence using limited cognitive resources. The study as well as the subsequent results and the resulting practical implications are presented and discussed in this paper.