Inter-individual and cross-linguistic diversity meet… the color lexicon

2nd of July 2024
Linguistic and Cognitive Science Meet Diversity (LCSmD) Workshop
Max Planck Institute for Evolutionary Anthropology (EVA)
Leipzig, DE

Dan Dediu
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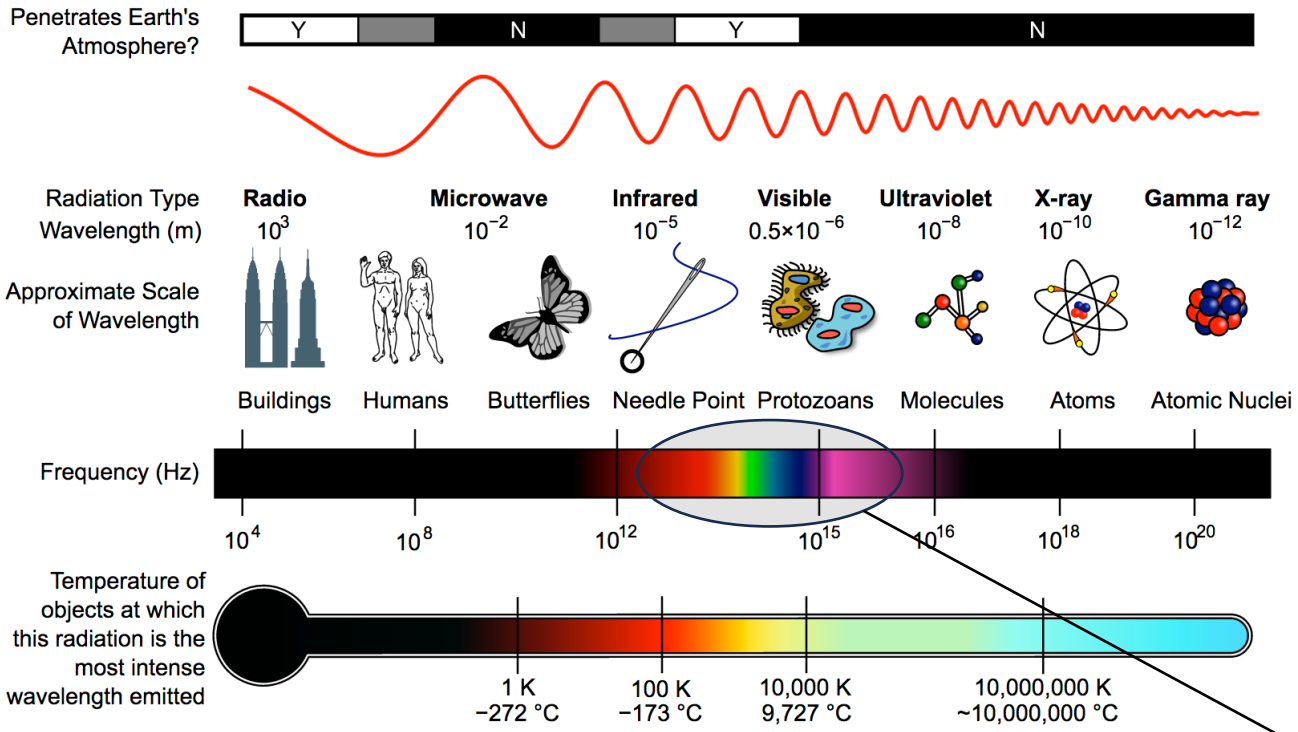
Department of Catalan Philology and General Linguistics
University of Barcelona Institute for Complex Systems (UBICS)
University of Barcelona, Spain

Part I: colour perception

Part I: colour perception

physics: colors ~ **frequency** of electromagnetic radiation **≈360nm – 780nm**

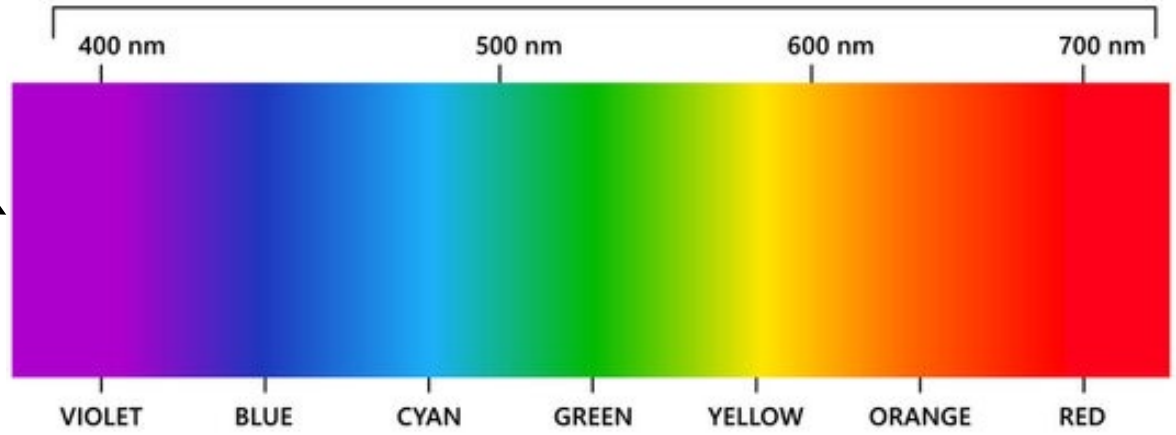


physics: 1D **continuum** ~ $\mathbb{R}^1$

sensation: ???

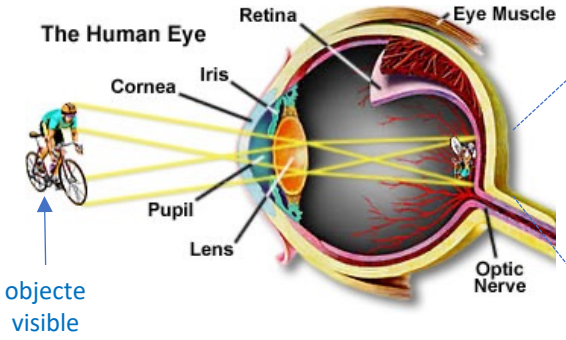
perception: ???

linguistics: **discrete** (structure ???)



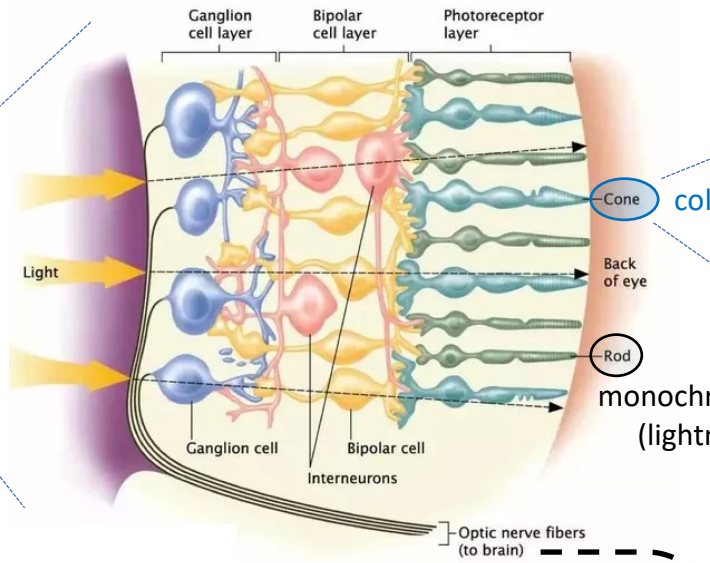
Part I: colour perception

Human **eye**



objecte visible

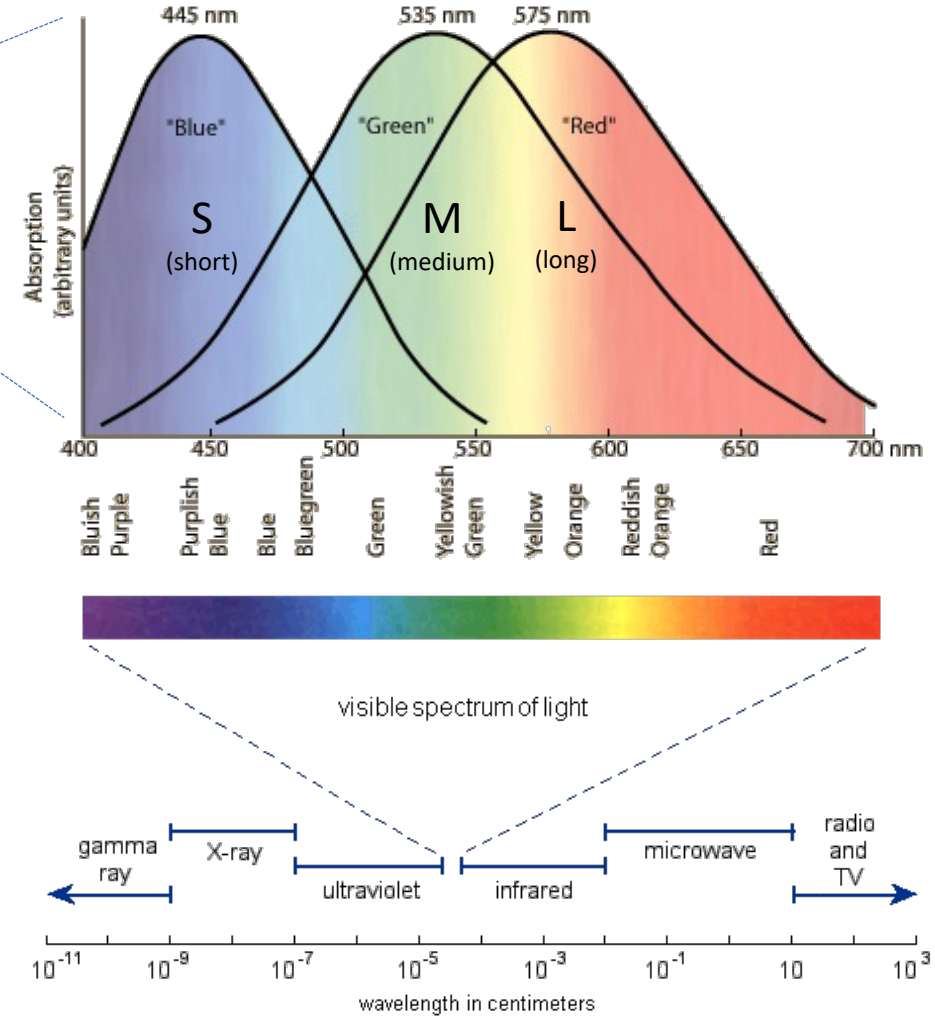
The **retina** (humans)



colors

monochromatic (lightness)

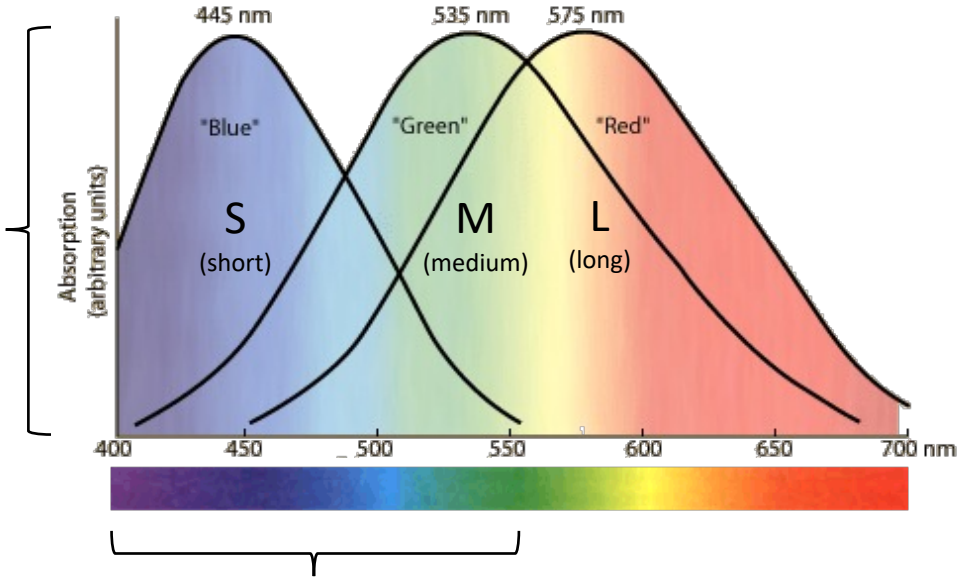
3 types of **cons**



Part I: colour perception

peaks relatively close (≈30nm)

sensitivity relatively non-specific



internal continuous and relatively large

important **intersection**

an isolated cone cannot tell apart color from intensity

must **compare** responses from **cones of different types**

(normal) human **color perception** is **3D**

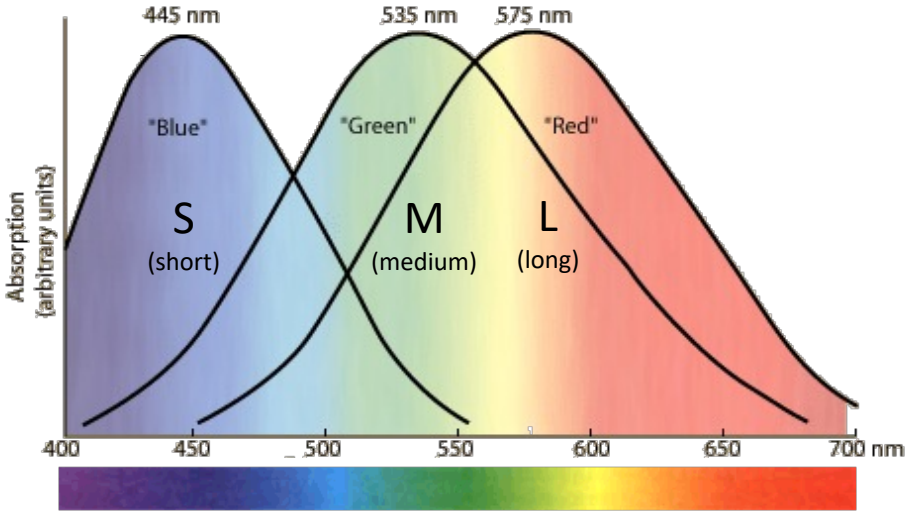
Part II: variation in colour perception

https://www.goodnewsnetwork.org/park-installs-device-colorblind-can-enjoy-dazzling-fall-colors-watch-joyful-reactions/

Part II: variation in colour perception

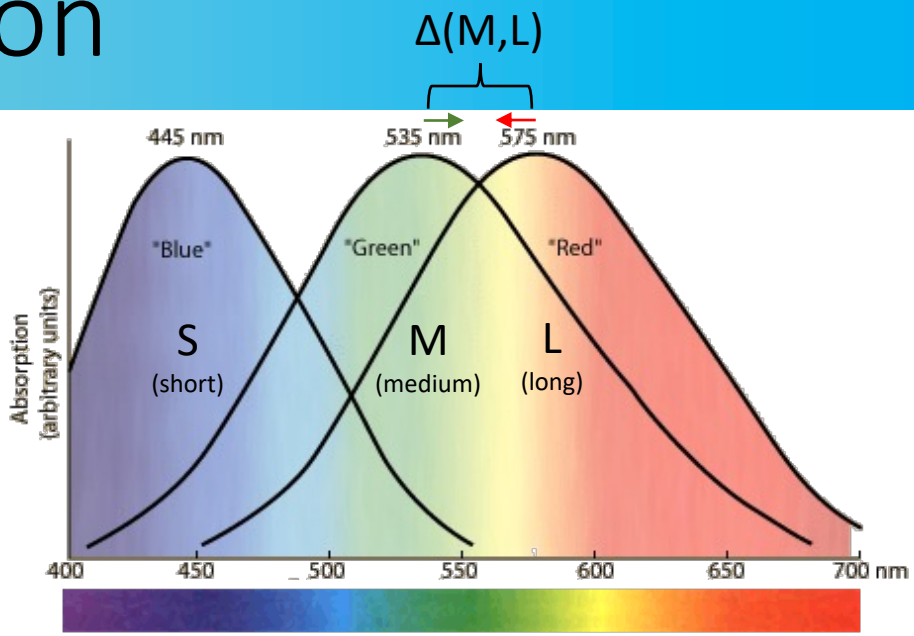
92% Normal Vision

← **normal** vision (**3**D)



Part II: variation in colour perception

92%	Normal Vision	← **normal** vision (**3**D)	
2.7%	Deuteranomaly	← **anomalous** trichromacy (**3**D)	
0.66%	Protanomaly	← **anomalous** trichromacy (**3**D)	



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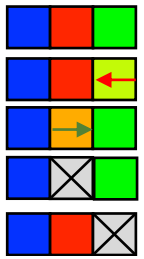
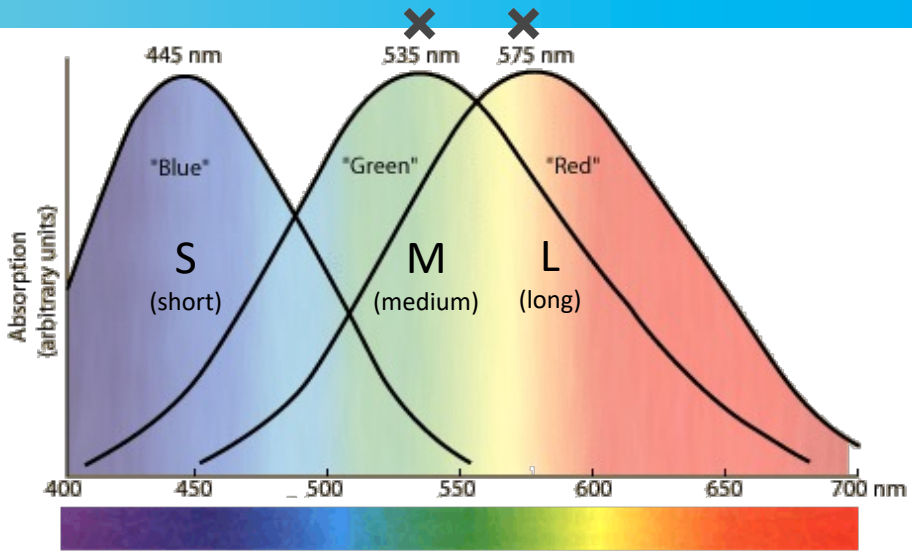
2.7%	Deuteranomaly	← **anomalous** trichromacy (**3**D)
0.66%	Protanomaly	← **anomalous** trichromacy (**3**D)
0.59%	Protanopia	← **dichromacy** (**2**D)
0.56%	Deuteranopia	← **dichromacy** (**2**D)





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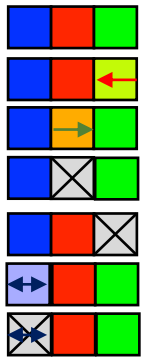
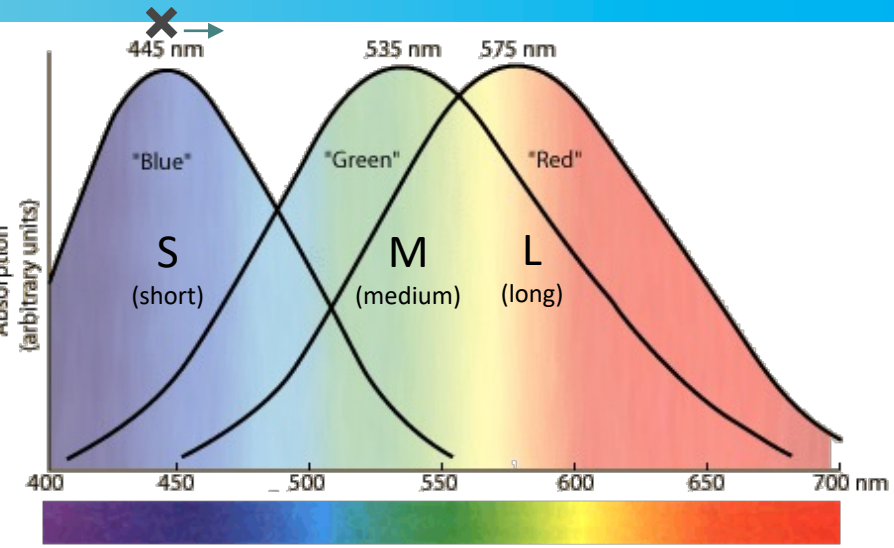
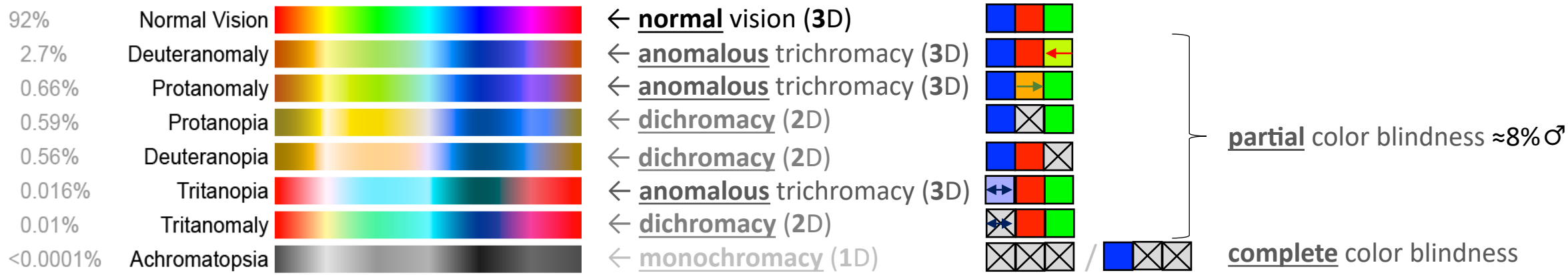
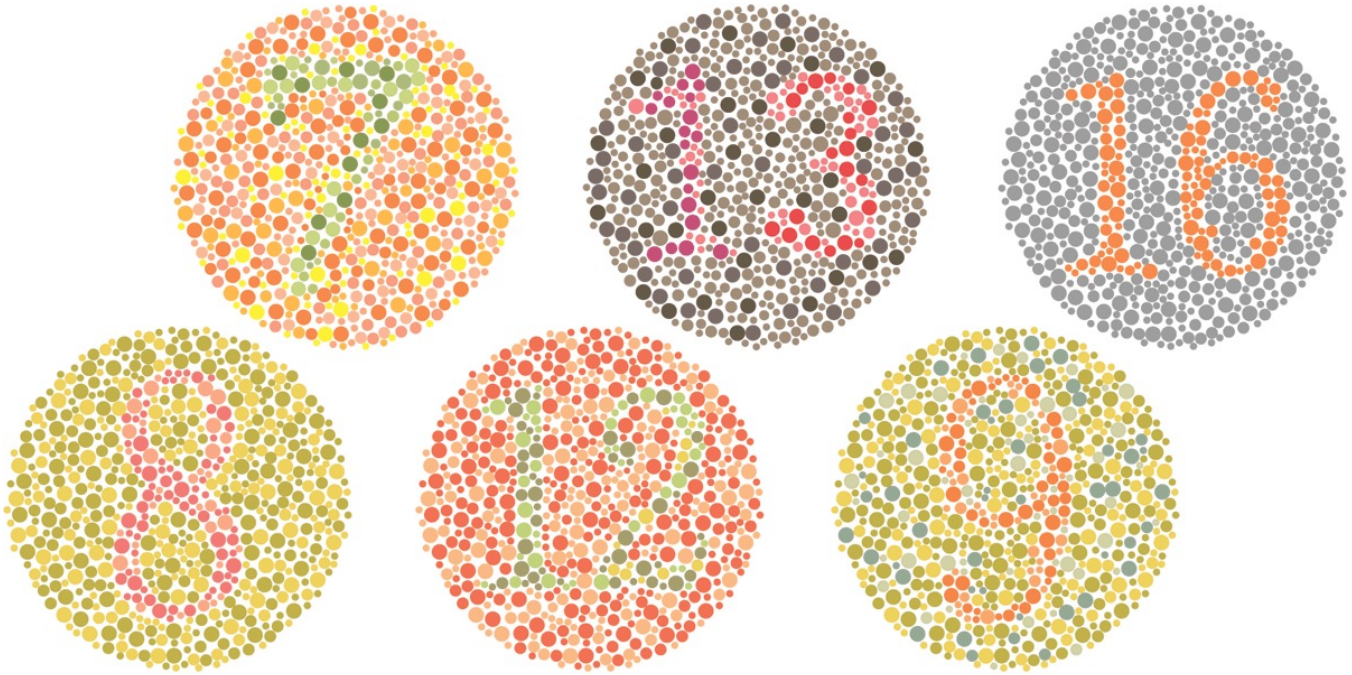
0.66%	Protanomaly	← **anomalous** trichromacy (**3**D)
0.59%	Protanopia	← **dichromacy** (**2**D)
0.56%	Deuteranopia	← **dichromacy** (**2**D)
0.016%	Tritanopia	← **anomalous** trichromacy (**3**D)
0.01%	Tritanomaly	← **dichromacy** (**2**D)



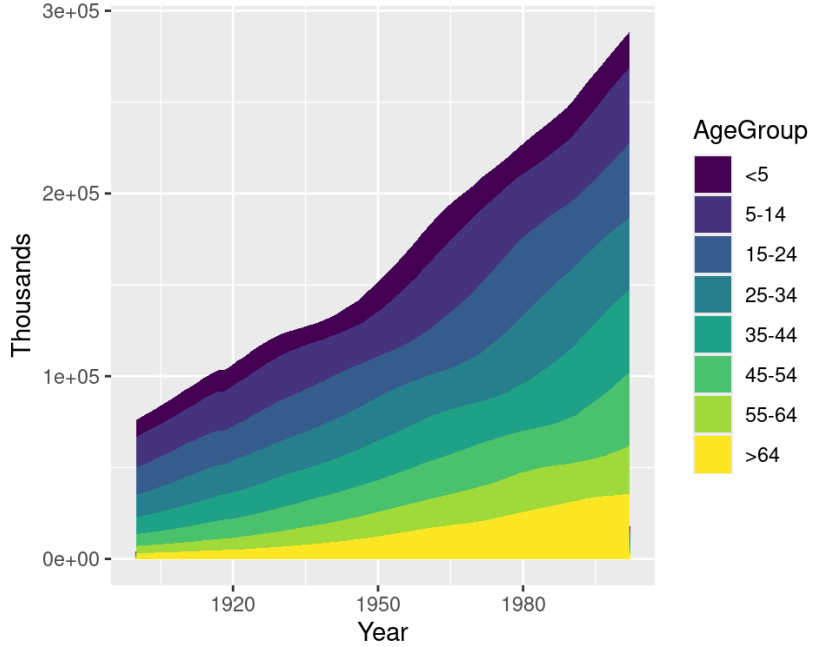


Part II: variation in colour perception

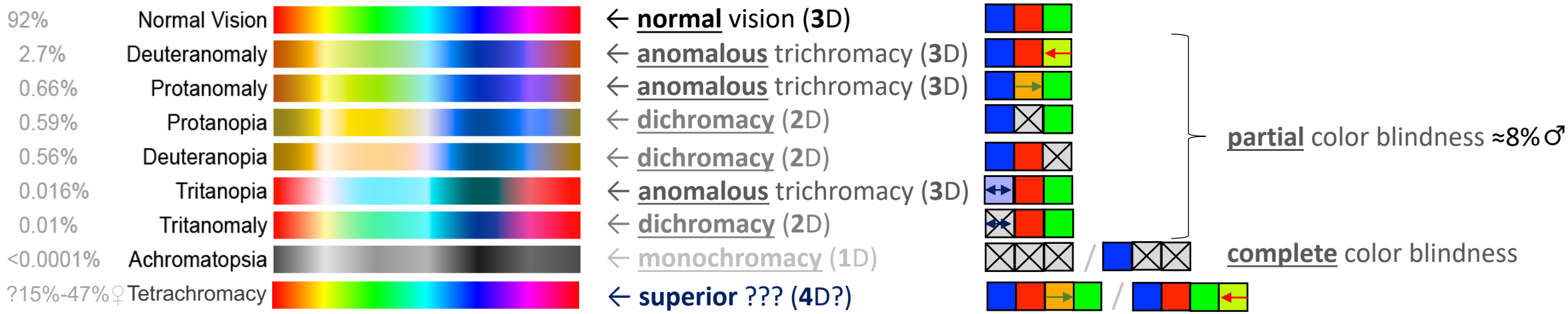


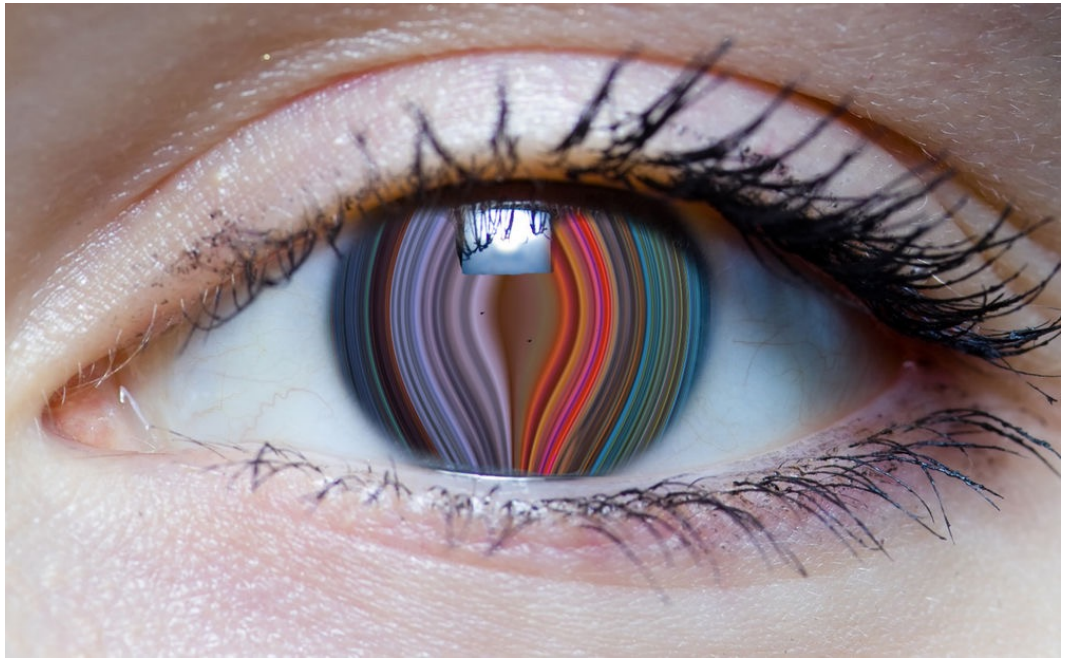


"color blind"-friendly palettes (e.g., viridis)



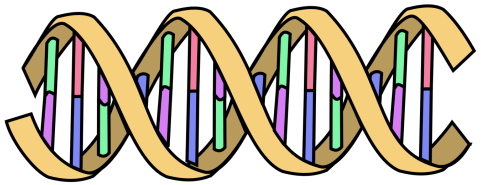
Part II: variation in colour perception

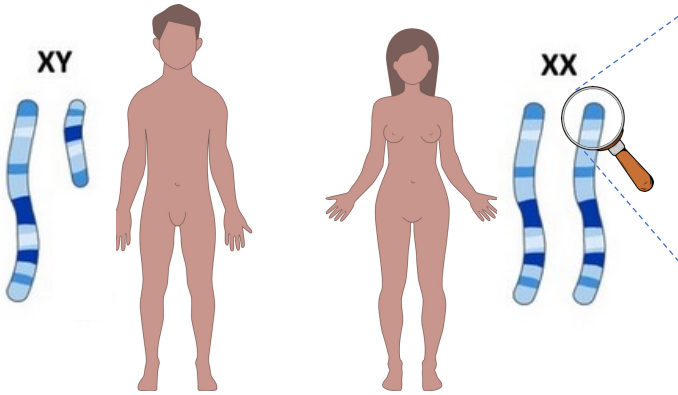


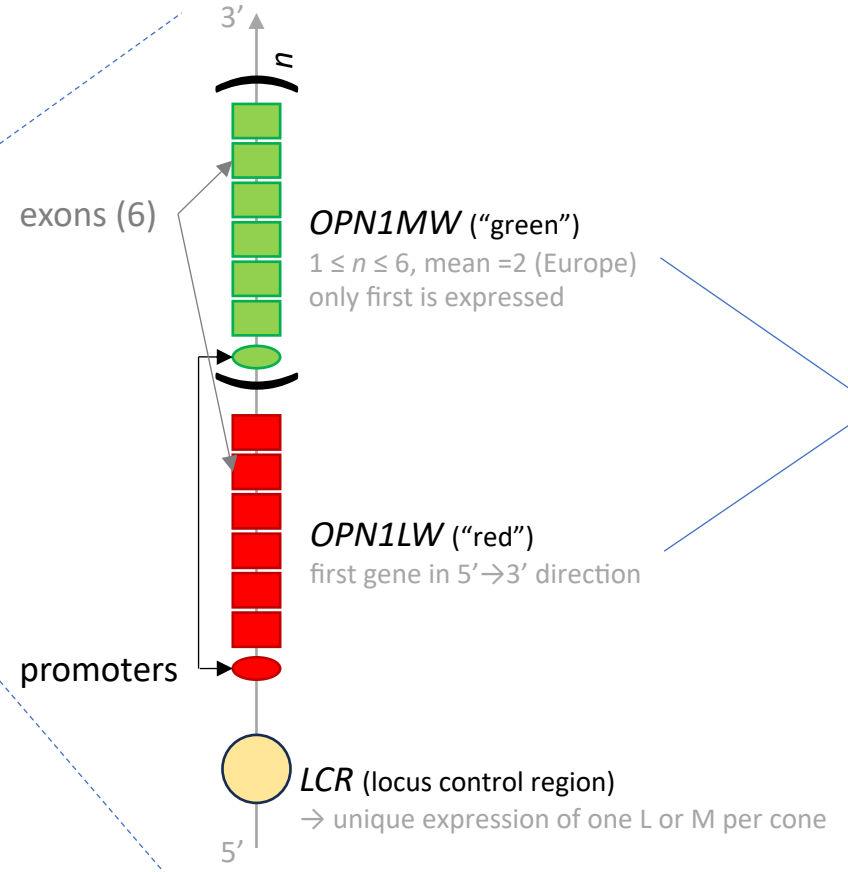


https://ms.memorialcogic.online/se/are-you-tetrachromatic.html

Part II: variation in colour perception





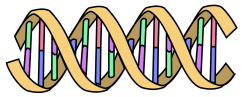


extremely similar (98%)
duplication of ancestral red gene
(after separation of Old and New World primates ~30–40 Mya)

Part II: variation in colour perception

inter-individual:

- **opsins** (“red”/“green” most frequent, ≈8%♂)



Part II: variation in colour perception

inter-individual:

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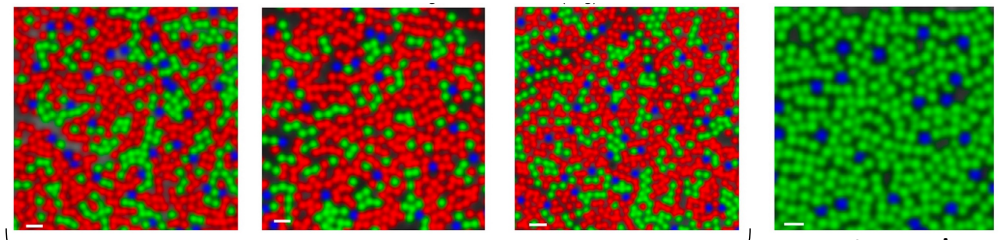
- **retinal mosacism**

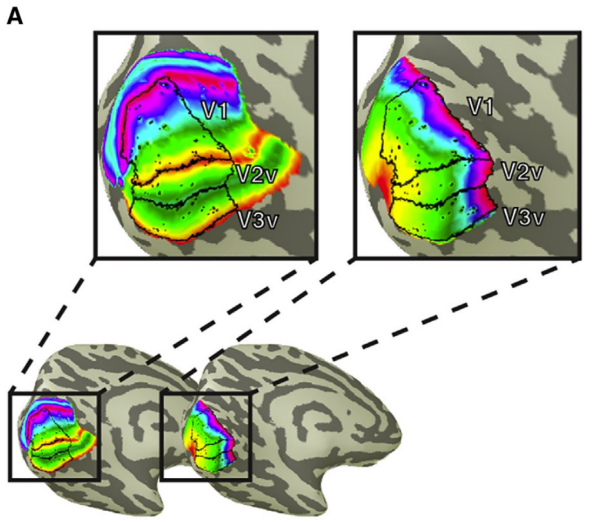


Carroll, J., & Conway, B. R. (2021). Color vision. In J. J. S. Barton & A. Leff (Eds.), *Handbook of Clinical Neurology* (Ch8, Vol. 178, pp. 131–153). Elsevier. doi:10.1016/B978-0-12-821377-3.00005-2

Part II: variation in colour perception

inter-individual:

- opsins (“red”/“green” most frequent, ≈8%♂)
- retinal mosacism
- **cortical procesing** (V1, V2, V4…)



Tregillus, K. E. M., Isherwood, Z. J., Vanston, J. E., Engel, S. A., MacLeod, D. I. A., Kuriki, I., & Webster, M. A. (2021). Color Compensation in Anomalous Trichromats Assessed with fMRI. *Current Biology*, **31**(5), 936-942.e4. doi:10.1016/j.cub.2020.11.039

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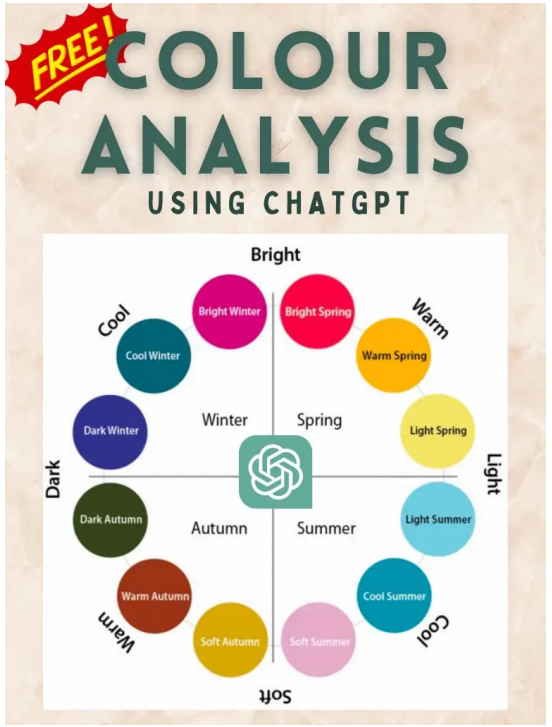

https://www.lemon8-app.com/iameleannn/7324484412521857538?region=sg&pid=website_seo_share

- cortical procesing (V1, V2, V4…)
- **compensation strategies** (postreceptor: contrast, lightness, rods, retinal inhomogeneities, language…)

Part II: variation in colour perception

inter-individual:

- opsins (“red”/“green” most frequent, ≈8%♂)
- retinal mosacism

https://stock.adobe.com/es/images/diverse-colorful-people-crowd-seamless-pattern-illustration-multi-color-rainbow-cartoon-characters-in-funny-children-doodle-style-friendly-community-or-kid-group-background-concept/461798371

- cortical procesing (V1, V2, V4…)
- compensation strategies (postreceptor: contrast, lightness, rods, retinal inhomogeneities, language…)

→ **multi-dimensional continuum** between effective monochromaticism and (potential) tetrachromacity

Part II: variation in colour perception

(between genders/sexes ?):

- (potential) tetrachromats - ♀ **only**
- ♀ may have some "**advantages**" (green-yellow, green-blue)

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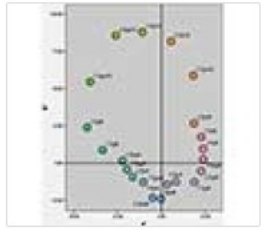
Ian J. Murray; Neil R. A. Parry; Declan J. McKeefry; Athanasios Panorgias

+ Author Affiliations

Journal of Vision January 2012, Vol.12, 18. doi:https://doi.org/10.1167/12.1.18

Journal of the Optical Society of America A Vol. 35, Issue 4, pp. B1-B10 (2018) • https://doi.org/10.1364/JOSAA.35.0000B1



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David Bimler and Valérie Bonnardel

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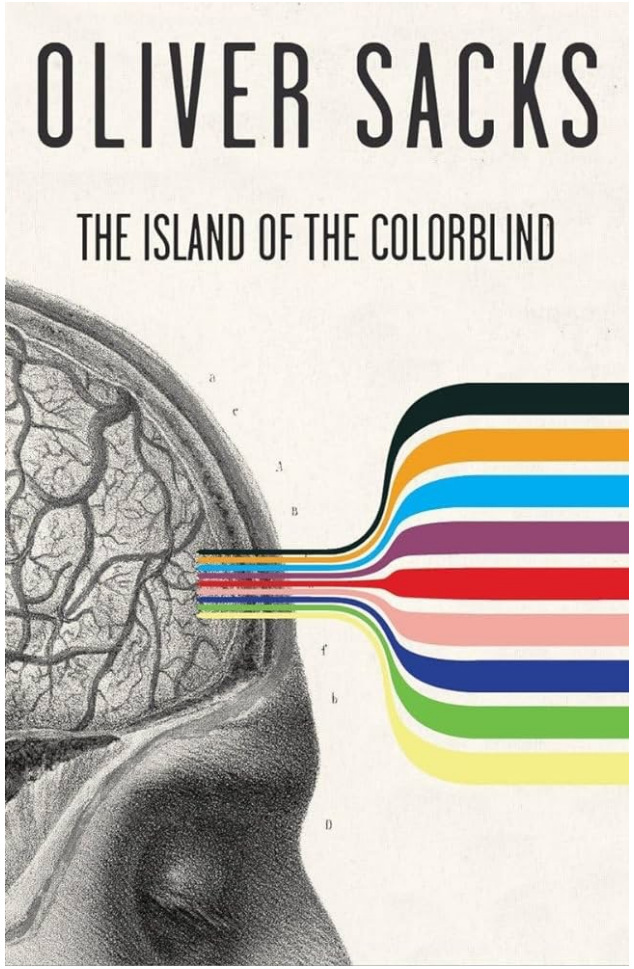
Part II: variation in colour perception

between groups:

- much **less well studied** & understood



https://www.noorimages.com/the-island-of-the-colorblind

~10% **achromatopsia** (rod monochromacy, **genetics**)
→ founder effect (1775)

Part II: variation in colour perception

between groups:

- much less well studied & understood

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Environment and culture shape both the colour lexicon and the genetics of colour perception

Mathilde Josserand, Emma Meeussen, Asifa Majid & Dan Dediu

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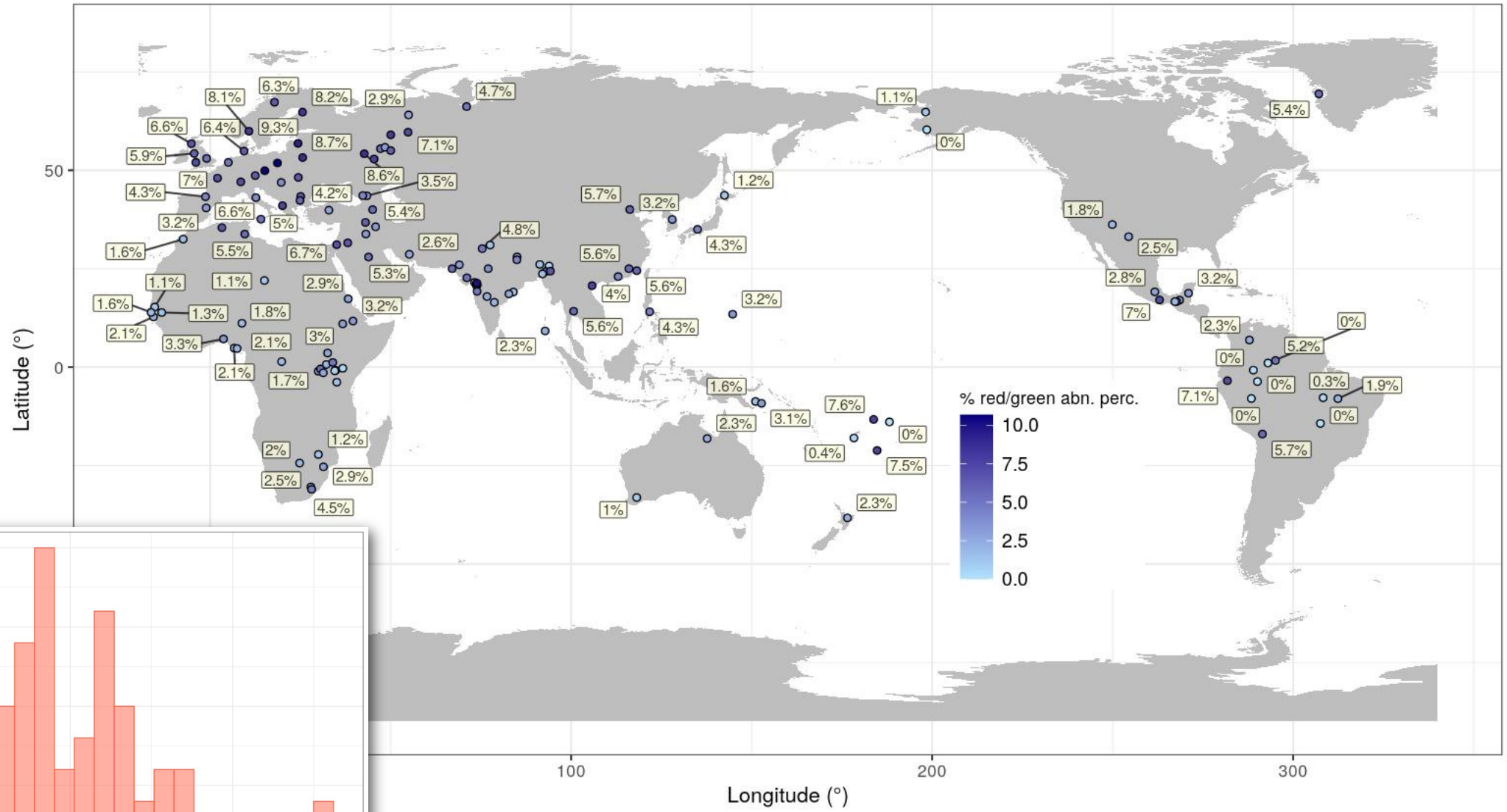
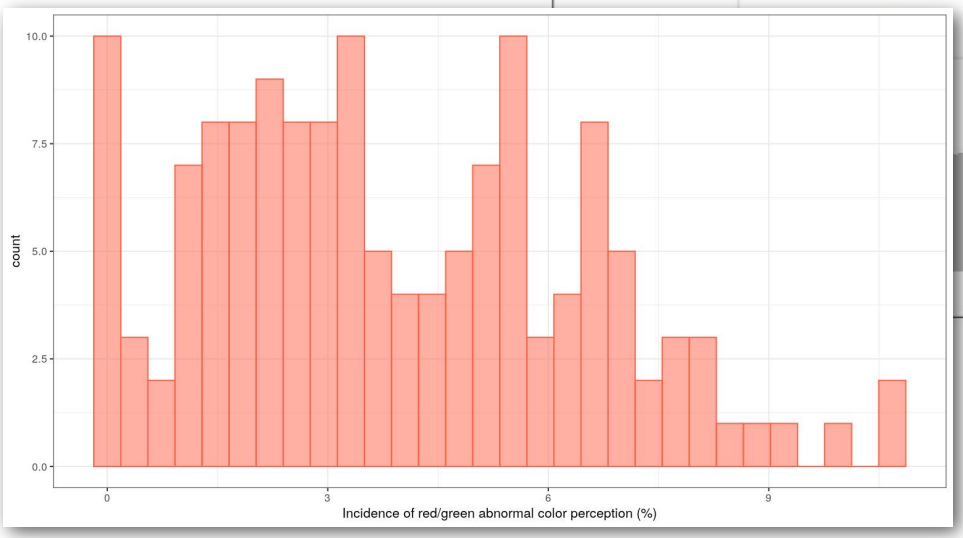
- **abnormal red-green** colour perception (**genetics**):
  - for ♂ **only**: % "colour blind" males in the population
  - 85 references (aka, published data)
  - collected with the Ishihara test (Ishihara, 1917), anomaloscope (Patent No. US3382025A, 1968), Holmgren-Thomson wool test (Thomson, 1880), or the Hardy-Rand-Rittler pseudoisochromatic plate test (Hardy, Rand, & Rittler, 1954)
  - **0.0% – 10.7%**, mean **3.9%**

Part II: variation in colour perception

between groups





Part II: variation in colour perception

between groups:

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- achromatopsia on Pingelap (genetics)
- abnormal red-green colour perception (genetics)
- **lens brunescence** (**environment**):

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ORIGINAL RESEARCH article

Front. Psychol.
Sec. Language Sciences
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Ultraviolet light affects the color vocabulary: evidence from 834 languages

Dan Dediu[1, 2, 3*]

Matters Arising | Open Access | Published: 01 February 2023

Reply to: Sunlight exposure cannot explain "grue" languages

Mathilde Josserand, Emma Meeussen, Dan Dediu & Asifa Majid

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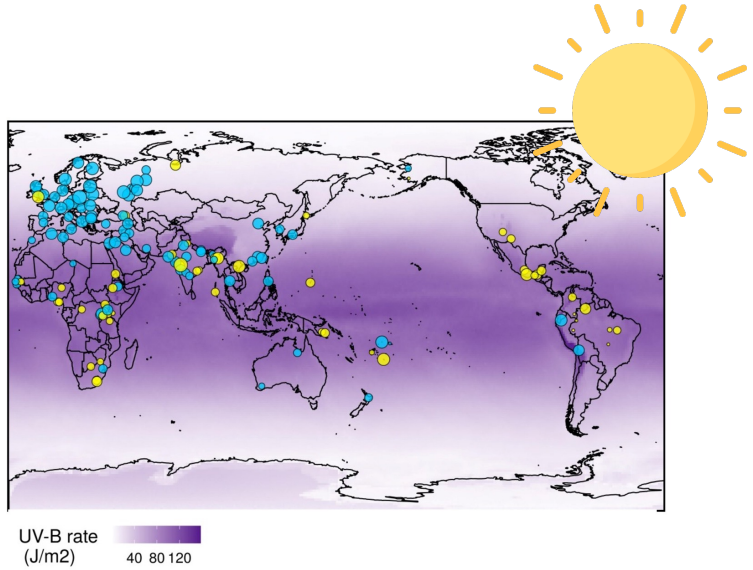
Part II: variation in colour perception

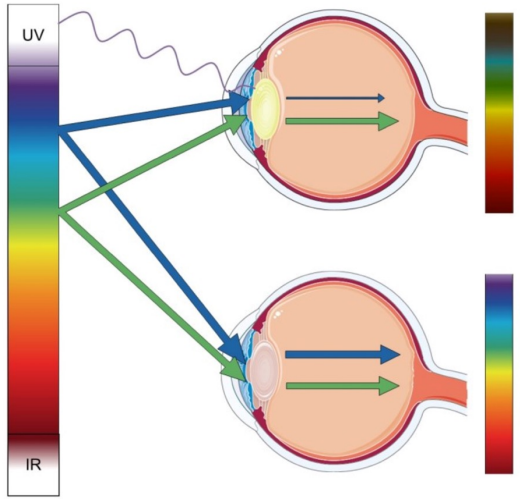
between groups:

- much less well studied & understood
- achromatopsia on Pingelap (genetics)
- abnormal red-green colour perception (genetics)
- **lens brunescence** (**environment**):
  - based on a previous hypothesis
  - UV(B) → **eye physiology** (**lifetime**)
  - **progressively reduced** perception of blue


Angela Brown


Delwin Lindsey





Lens brunescence → perception of blue


Lens Brunescence

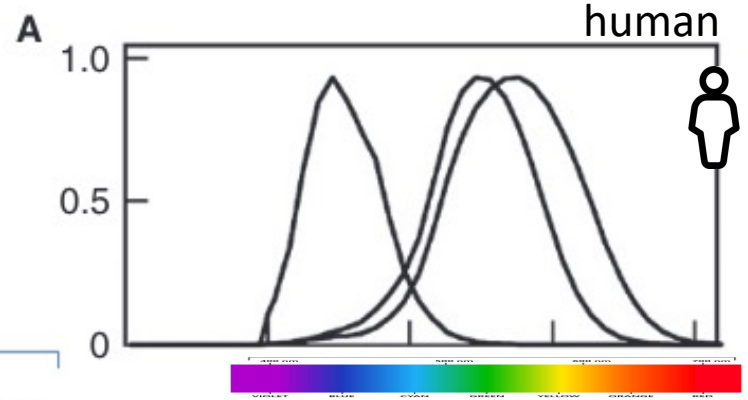
Normal colour vision →

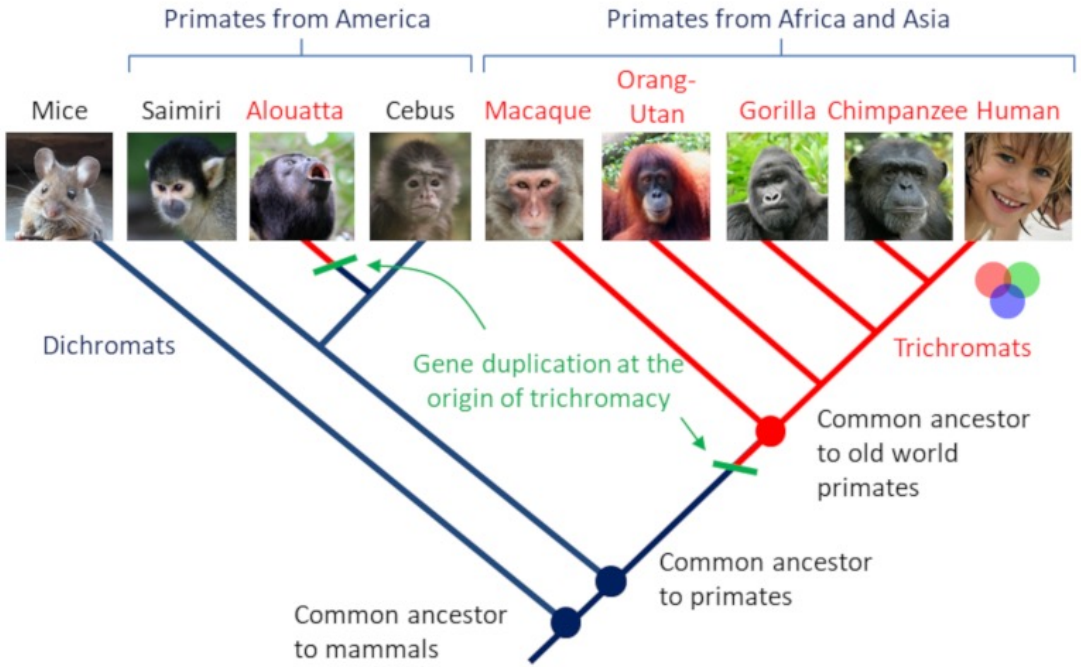

Normal

Part II: variation in colour perception

between species:

- human-like trichromatic vision is… **WEIRD**





https://www.encyclopedie-environnement.org/en/zoom/evolution-of-colour-vision-in-mammals-and-primates/

Part II: variation in colour perception

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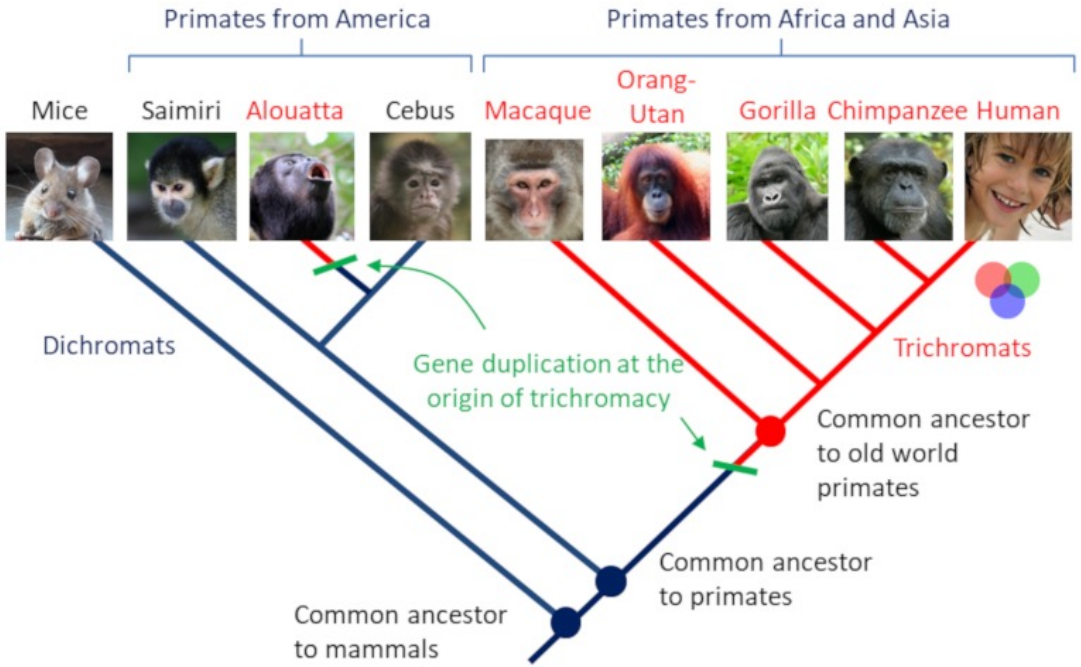

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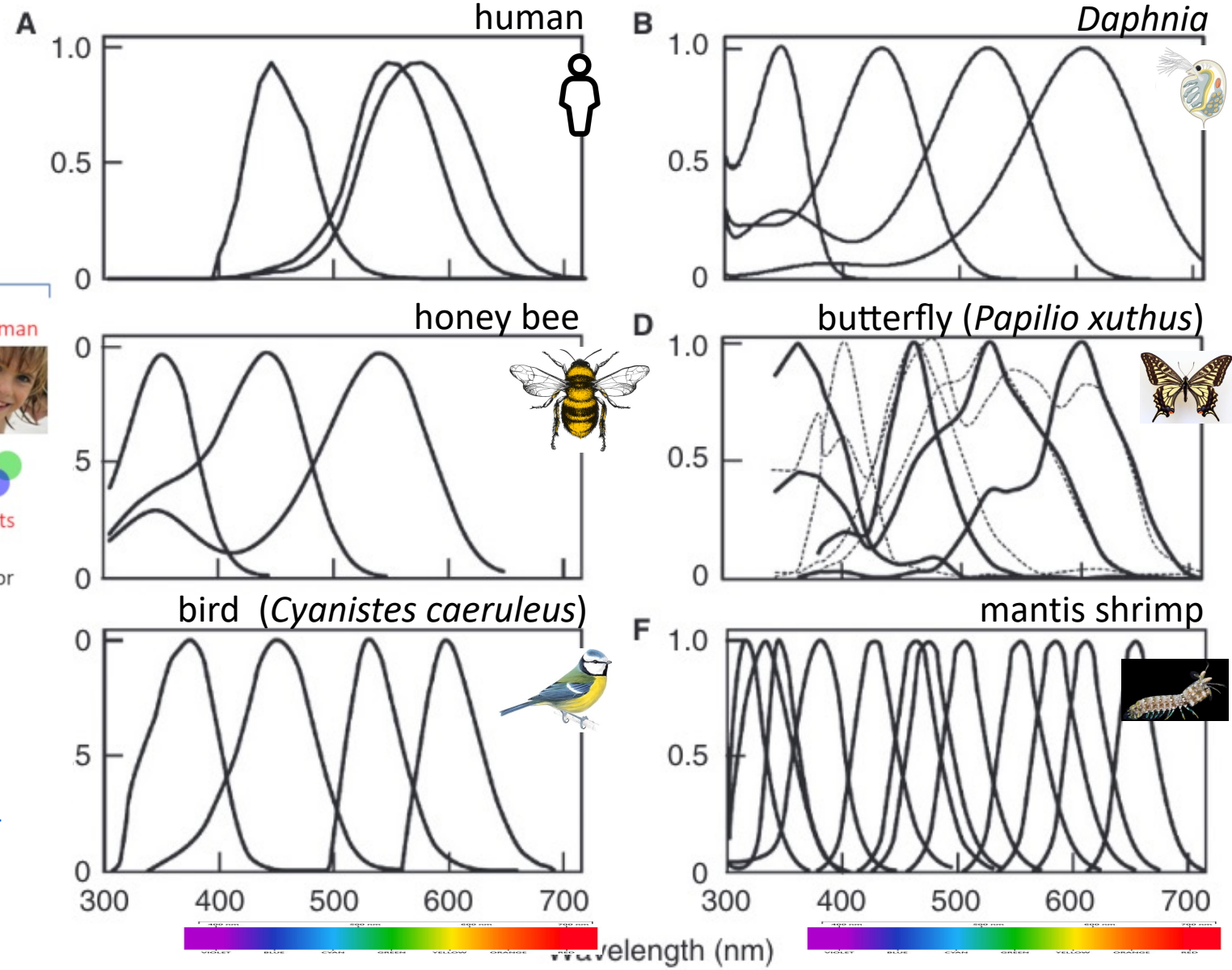
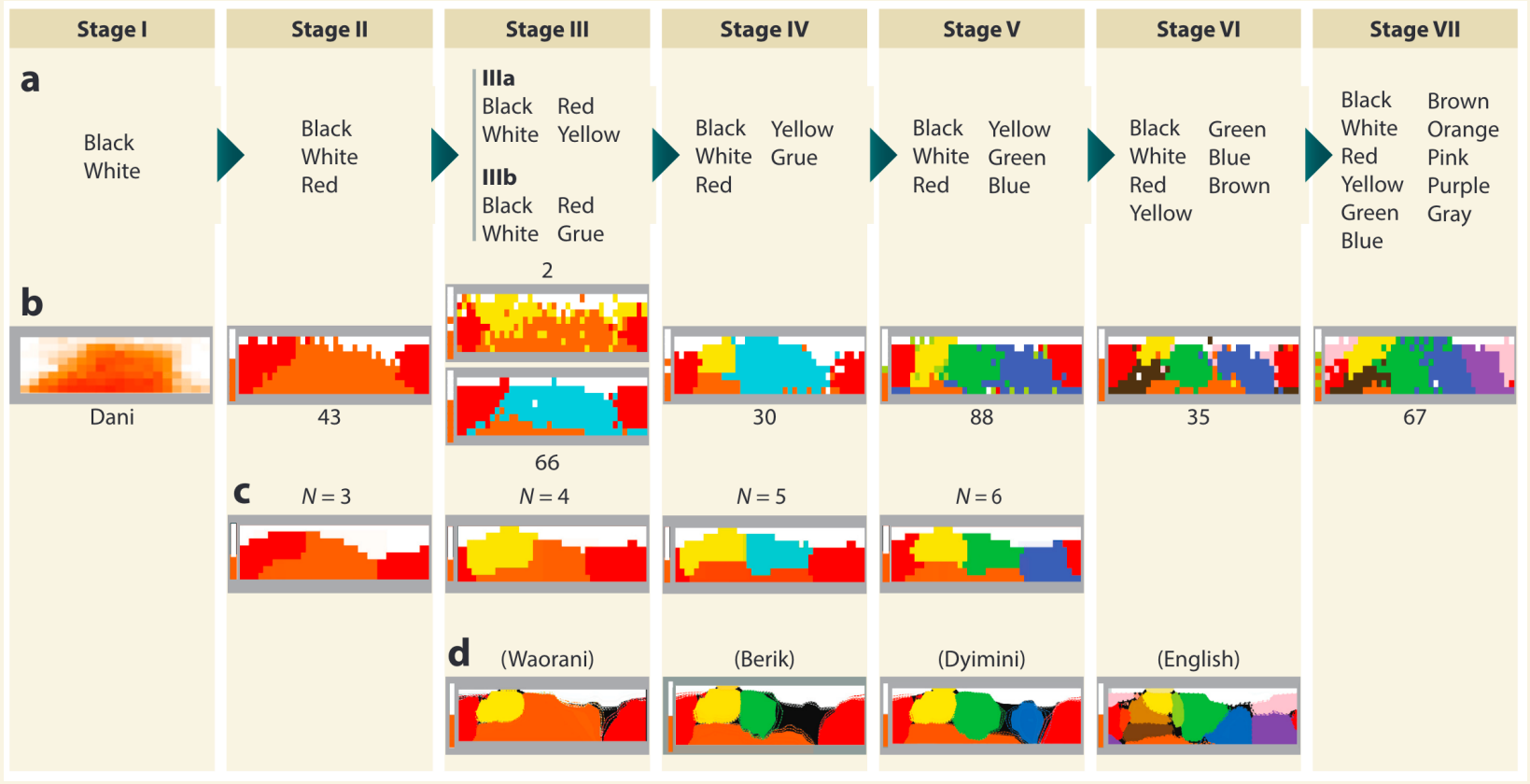


Marshall, J., & Arikawa, K. (2014). Unconventional colour vision. *Current Biology*, *24*(24), R1150–R1154. doi:10.1016/j.cub.2014.10.025

Part III: does it matter?



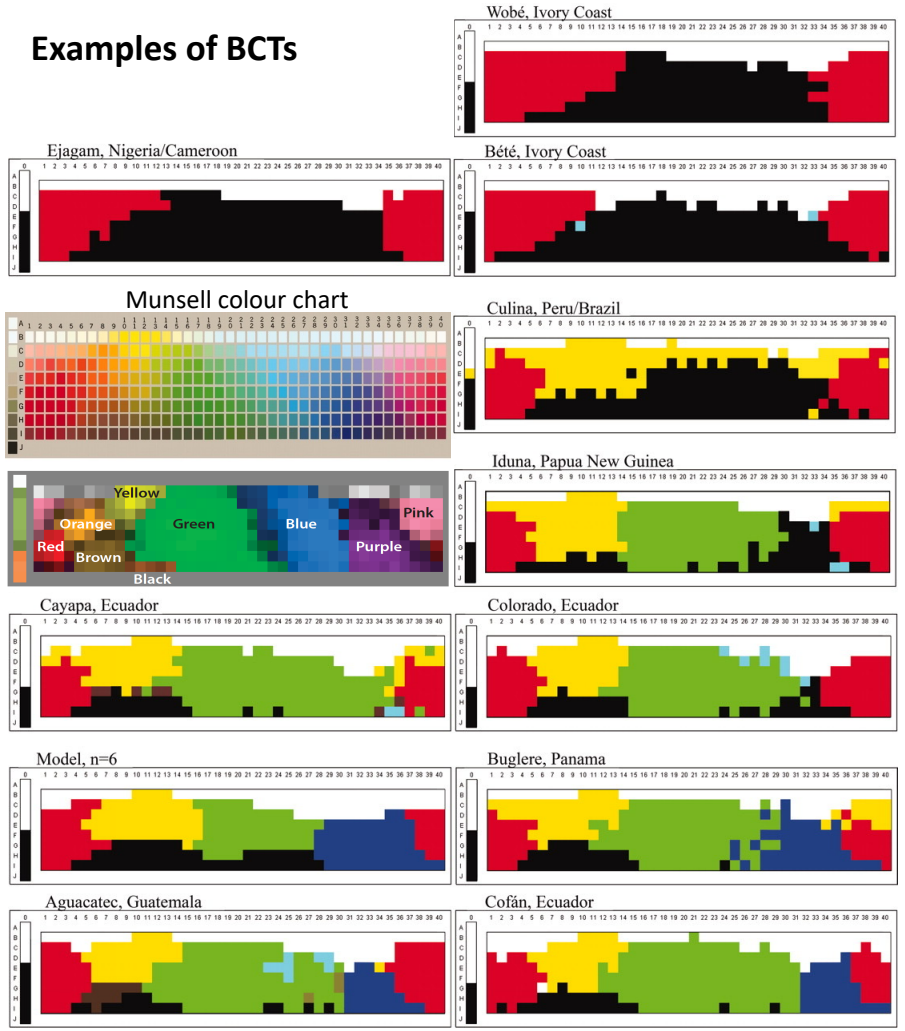
Lindsey, D. T., & Brown, A. M. (2021). Lexical Color Categories. *Annual Review of Vision Science*, *7*(1), 605–631. doi:10.1146/annurev-vision-093019-112420

Intermezzo: the colour lexicon

"**Basic color terms**" (**BCTs**; Berlin & Kay, 1969; Lindsey & Brown, 2021):

- **single** (non-composite) "word" (no "reddish")
- **not contained** in another term (no "scarlet")
- **common** usage and **general** (no "blond")

Examples of BCTs



Regier, T., Kay, P., & Khetarpal, N. (2007). Color Naming Reflects Optimal Partitions of Color Space. *PNAS*, *104*, 1436–1441. doi:10.1073/pnas.0610341104

Lindsey, D. T., & Brown, A. M. (2021). Lexical Color Categories. *Annual Review of Vision Science*, ***7***(1), 605–631. doi:10.1146/annurev-vision-093019-112420

The World Color Survey

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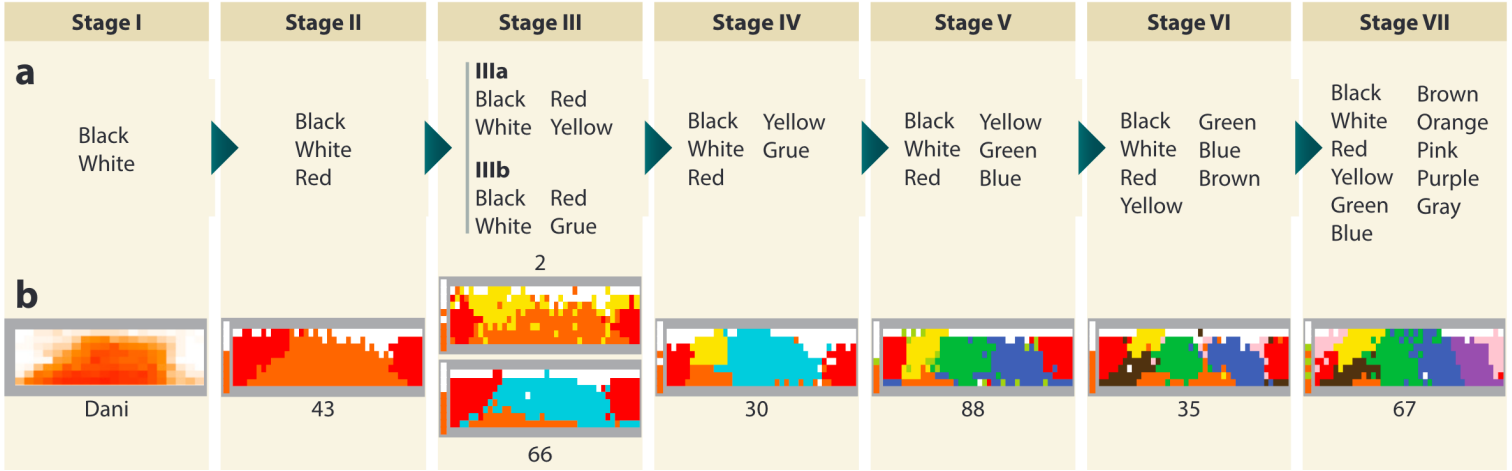
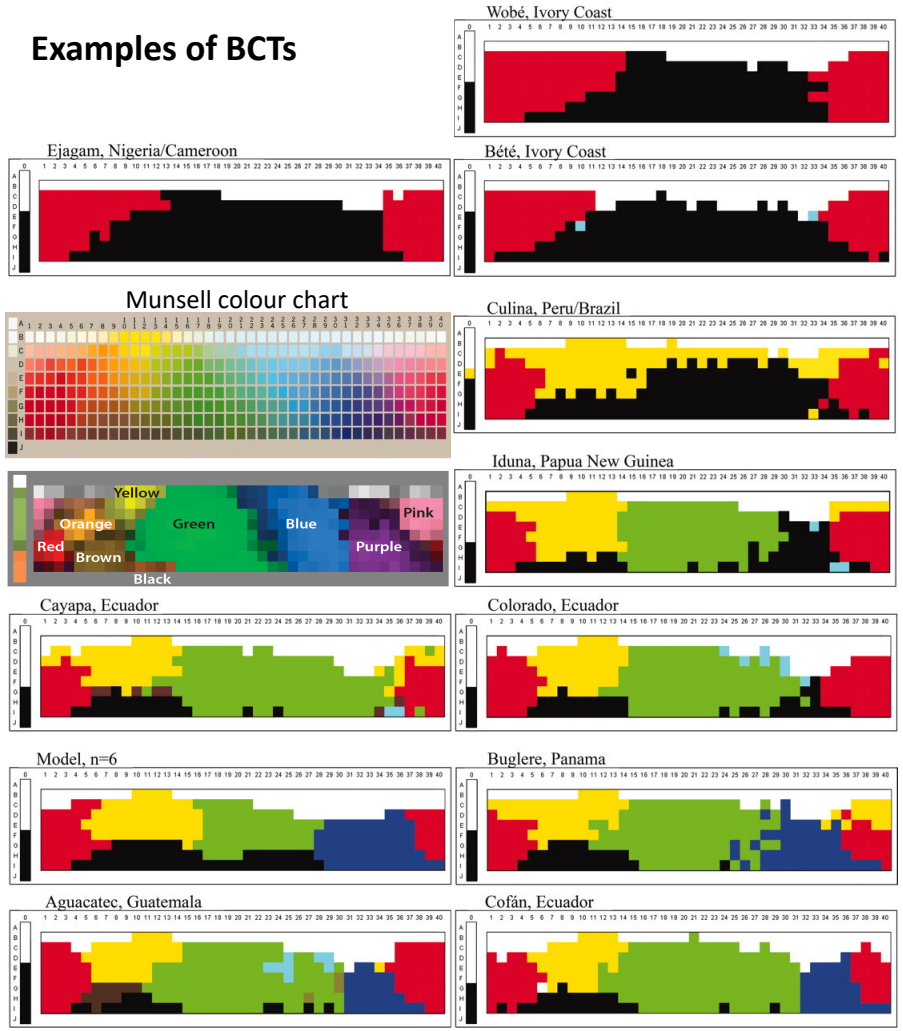
"Evolution" of BCTs

Berlin B, Kay P. 1969. Basic Color Terms: Their Universality and Evolution. Berkeley: Univ. Calif. Press (Lindsey & Brown, 2021)



→ "universality" wrt the location of the focal colours (the "centres")
→ variation in their number & boundaries
→ "universal" evolutionary sequence

Examples of BCTs



Regier, T., Kay, P., & Khetarpal, N. (2007). Color Naming Reflects Optimal Partitions of Color Space. *PNAS*, *104*, 1436–1441. doi:10.1073/pnas.0610341104

Lindsey, D. T., & Brown, A. M. (2021). Lexical Color Categories. *Annual Review of Vision Science*, ***7***(1), 605–631. doi:10.1146/annurev-vision-093019-112420

The World Color Survey

Intermezzo: the colour lexicon

beyond BCTs:

- “colour categories of English speakers”
- 600 colour stimuli
- 20,000 free names
- 1,000 participants
- http://colournaming.org

PLOS ONE

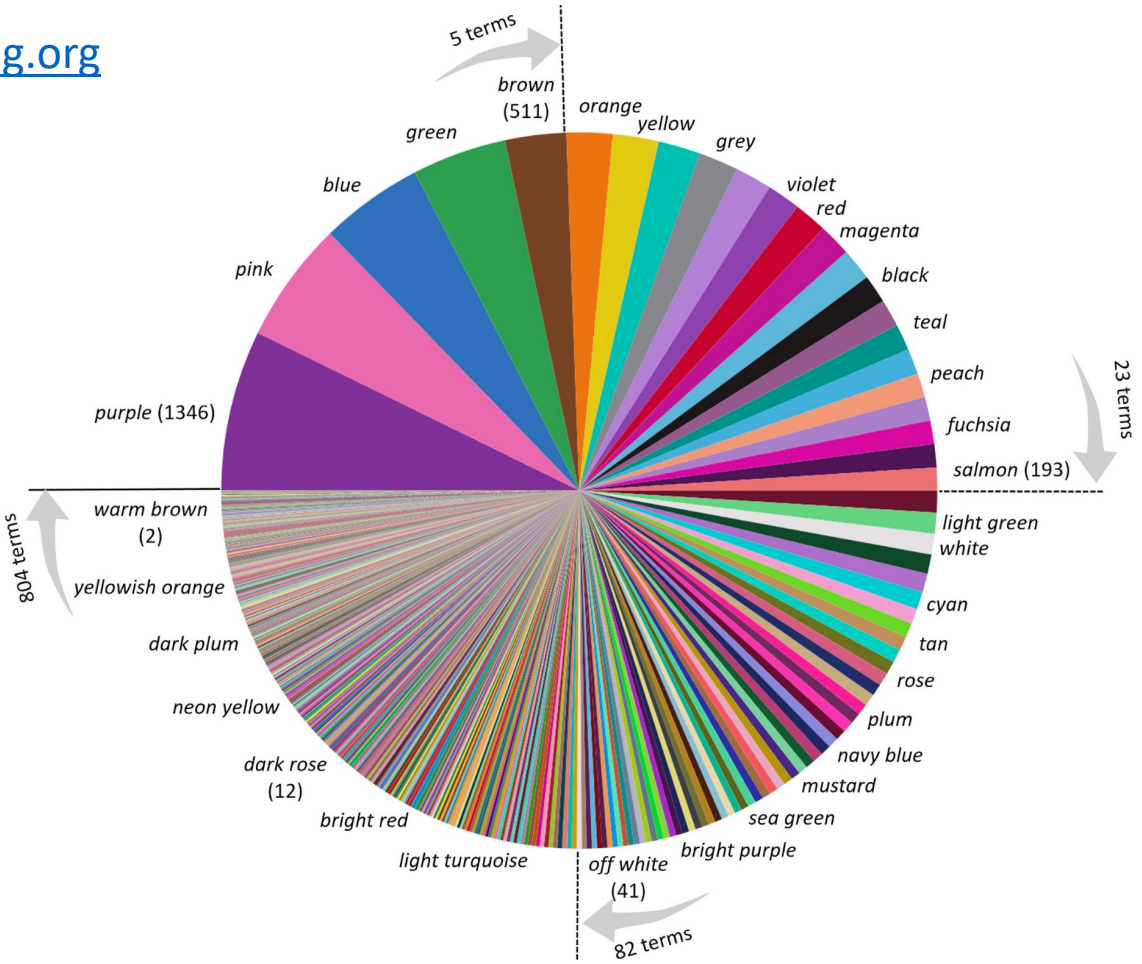
RESEARCH ARTICLE

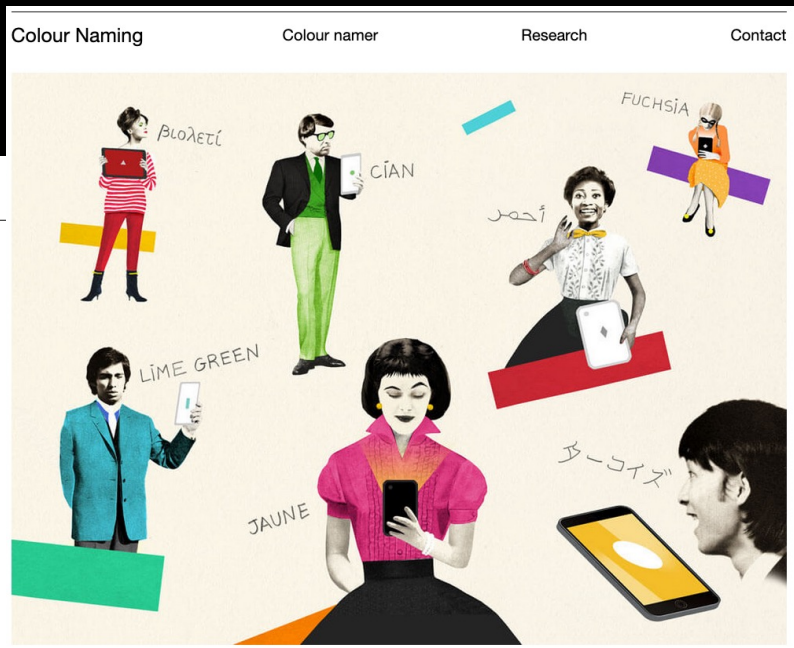
Categorical colour geometry

Lewis D. Griffin*, Dimitris Mylonas

Computer Science, UCL, London, United Kingdom

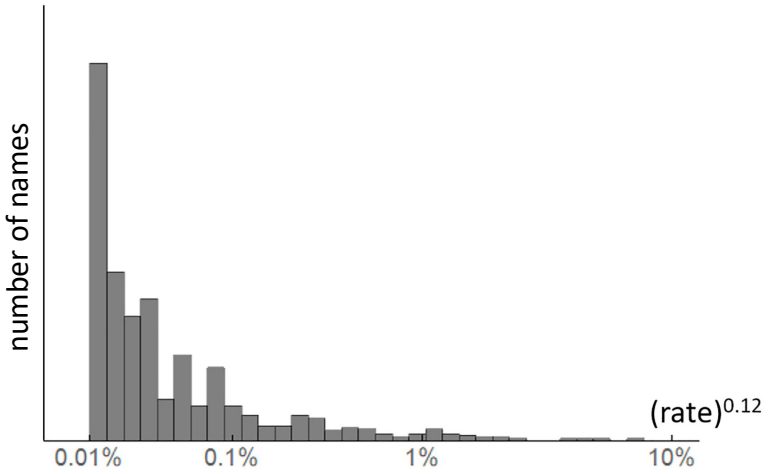
* l.griffin@cs.ucl.ac.uk





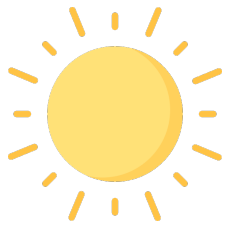
Let's play a game, how many colours can you name?

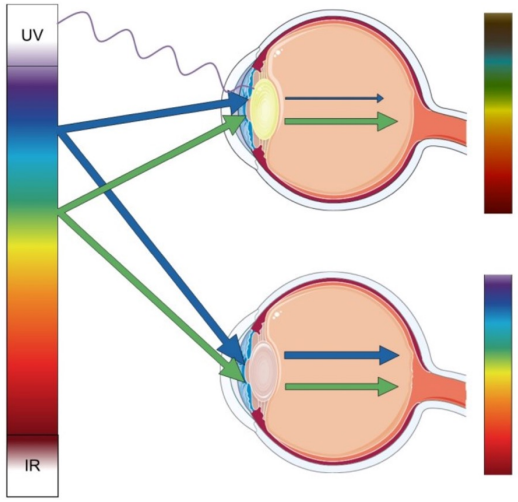
Welcome to Colour Naming, an online experiment designed to collect colour names in multiple languages with their corresponding colour ranges. You will be asked to name a series of colour samples and provide information about your cultural background and viewing conditions. You are free to omit any question and you may withdraw at any time without penalty. Participation in this study is strictly anonymous and voluntary.



Part III: does it matter?

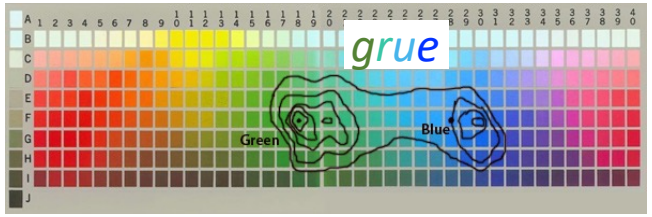
case study: UV(B) → lens brunescence → colour vocabulary





Lens brunescence → Worse perception of blue colours? → No specific term for blue in the colour vocabulary

Normal color vision



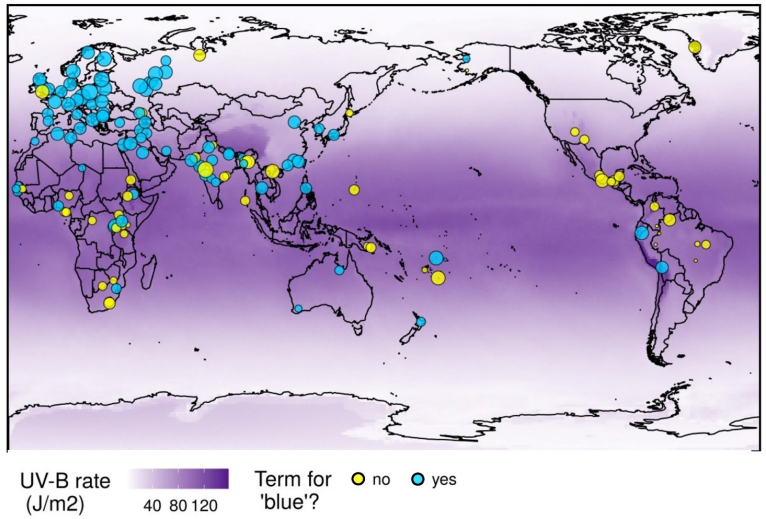
The CULTURE ?

(exposure to **colour dyeing** techniques, **coloured artefacts**…)

The ENVIRONMENT ?

Part III: does it matter?

case study: UV(B) → lens brunescence → colour vocabulary



← 142 POPULATIONS (32 families)

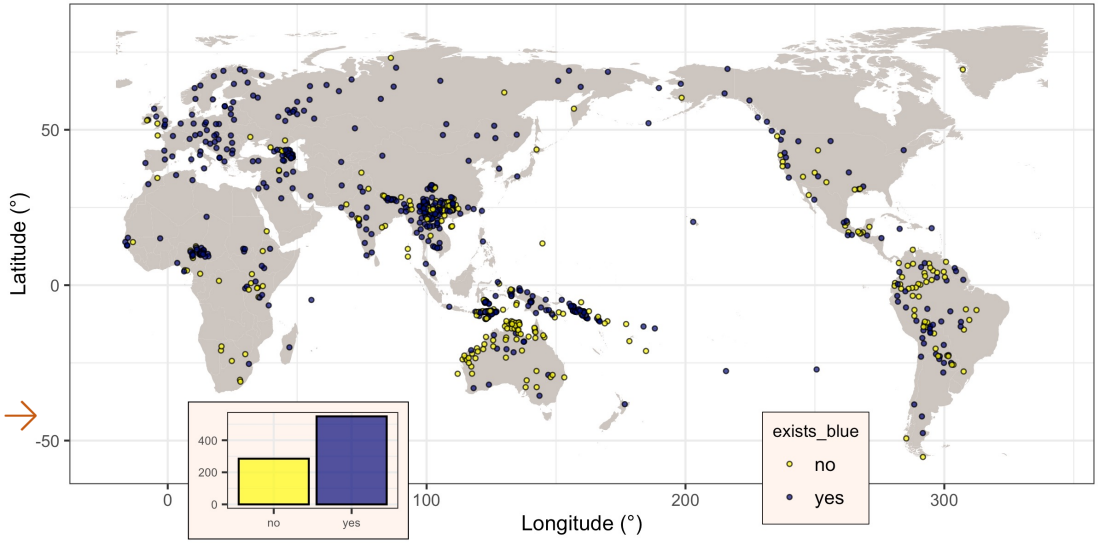
Meeussen, E. (2015).

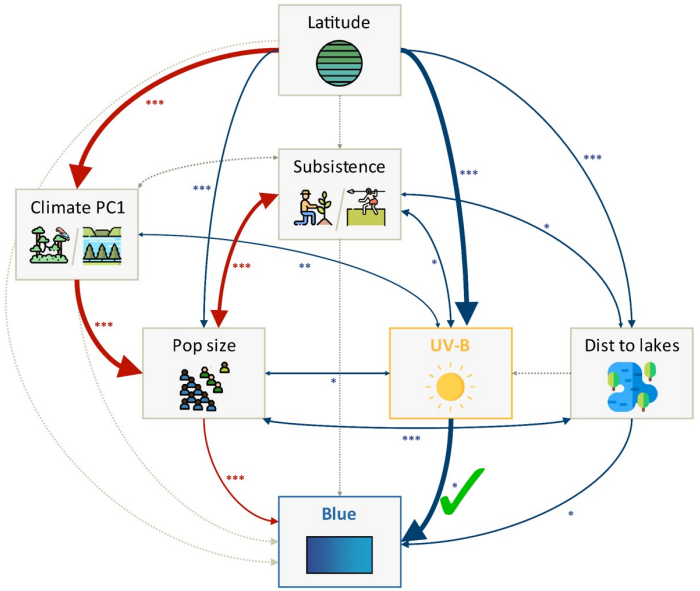
- dictionaries
- wordlists
- Brown & Lindsey (2004)

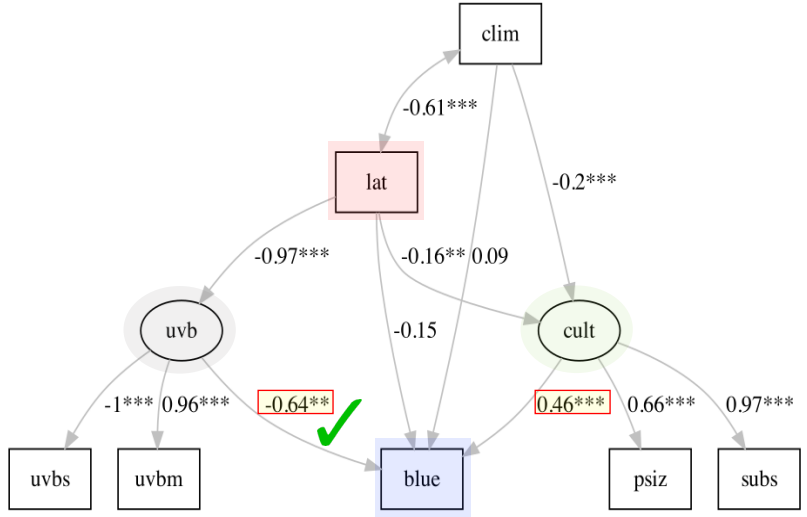
+

834 POPULATIONS (155 families) →

- dictionaries
- wordlists
- experts
- CLICS + Lexibank







Part III: does it matter?

in general:

- how does the **cross-linguistic variation** in the color lexicon emerge?
- and does the **variation in color perception** influence it?

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ELSEVIER

Journal of Theoretical Biology
Volume 253, Issue 4, 21 August 2008, Pages 680-700

Population heterogeneity and color stimulus heterogeneity in agent-based color categorization

Natalia L. Komarova [a], Kimberly A. Jameson [b]

- computer (agent-based) models
- "normal" & "anomalous" agents (**population heterogeneity**)
- perceptual distance (**color space heterogeeenity**)

→ **symmetry breaking** → color categories

Journal of the Optical Society of America A Vol. 26, Issue 6, pp. 1414-1423 (2009) • https://doi.org/10.1364/JOSAA.26.001414

OPTICA PUBLISHING GROUP

Evolutionary models of color categorization. I. Population categorization systems based on normal and dichromat observers

Kimberly A. Jameson and Natalia L. Komarova

Journal of the Optical Society of America A Vol. 26, Issue 6, pp. 1424-1436 (2009) • https://doi.org/10.1364/JOSAA.26.001424

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Evolutionary models of color categorization. II. Realistic observer models and population heterogeneity

Kimberly A. Jameson and Natalia L. Komarova

Author Information ▾ Find other works by these authors ▾

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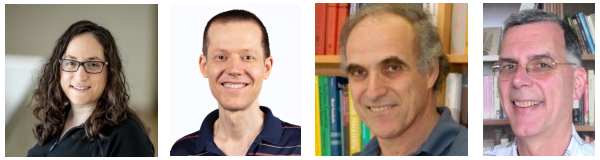


PNAS

Efficient compression in color naming and its evolution

Noga Zaslavsky, Charles Kemp, Terry Regier, and Naftali Tishby Authors Info & Affiliations

Edited by James L. McClelland, Stanford University, Stanford, CA, and approved June 18, 2018 (received for review January 11, 2018)

July 18, 2018 | 115 (31) 7937-7942 | https://doi.org/10.1073/pnas.1800521115

TOPICS IN COGNITIVE SCIENCE

Topics in Cognitive Science 11 (2019) 207–219

Color Naming Reflects Both Perceptual Structure and Communicative Need

Noga Zaslavsky,[a,b] Charles Kemp,[c] Naftali Tishby,[a,d] Terry Regier[b,e]

COGNITIVE NEUROPSYCHOLOGY
2020, VOL. 37, NOS. 5–6, 312–324
https://doi.org/10.1080/02643294.2019.1604502

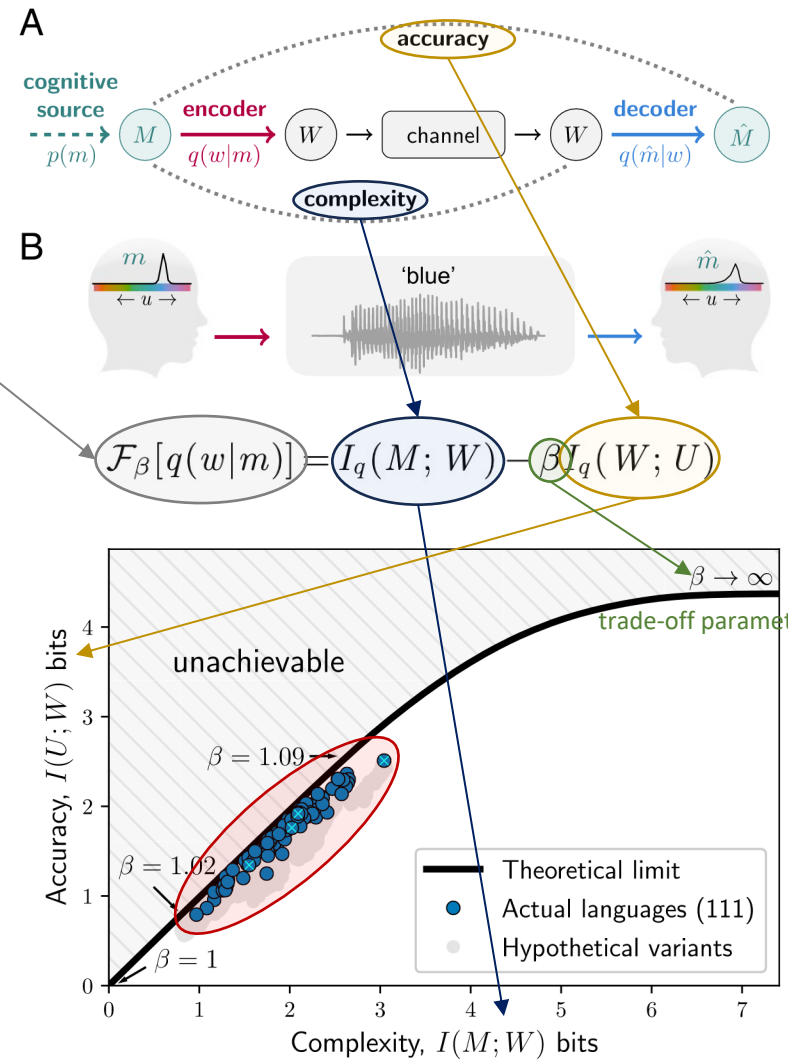
Communicative need in colour naming

Noga Zaslavsky[a,b], Charles Kemp[c], Naftali Tishby[a,d] and Terry Regier[b,e]

information theory (Shannon):

- not clear how to include **inter-individual variation**?
- **between-population variation**

information bottleneck objective function



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frontiers in Psychology

ORIGINAL RESEARCH
published: 21 June 2021
doi: 10.3389/fpsyg.2021.626118

Interindividual Variation Refuses to Go Away: A Bayesian Computer Model of Language Change in Communicative Networks

Mathilde Josserand, Marc Allassonnière-Tang, François Pellegrino and Dan Dediu*

Laboratoire Dynamique Du Langage UMR 5596, Université Lumière Lyon 2, Lyon, France

Diversity rules: the influence of a minority on language change

(EvoLang2024 & *in preparation*)

Mathilde Josserand[1], François Pellegrino[1] , Dan Dediu[2,3,4], & Limor Raviv[5]*

[1] Laboratoire Dynamique du Langage, Université Lyon 2 - CNRS UMR 5596, Lyon, France
[2] Department of Catalan Philology and General Linguistics, University of Barcelona, Barcelona, Spain
[3] University of Barcelona Institute for Complex Systems (UBICS), Barcelona, Spain
[4] Catalan Institute for Research and Advanced Studies (ICREA), Barcelona, Spain
[5] Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands

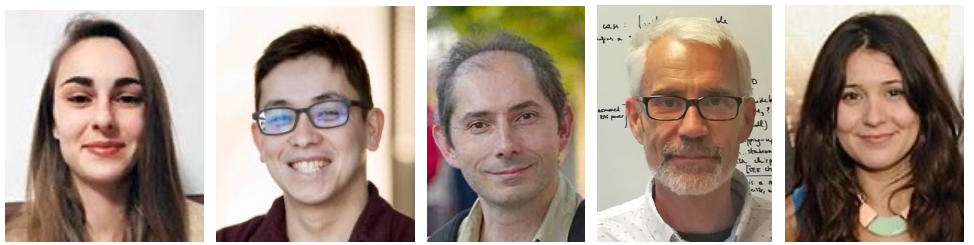
COGNITIVE SCIENCE
A Multidisciplinary Journal

Regular Article

How Network Structure Shapes Languages: Disentangling the Factors Driving Variation in Communicative Agents

Mathilde Josserand ✉, Marc Allassonnière-Tang, François Pellegrino, Dan Dediu, Bart de Boer

First published: 11 April 2024 | https://doi.org/10.1111/cogs.13439



Conclusions: the colour manifesto!

https://openart.ai/home

color is a (nearly) **perfect case study** because:

- mapping of a **continuous** ($\mathbb{R}^1$) space → **discrete** (finite small) vocabulary
- **genetics**, **anatomy**, **physiology**, **neurocognition**: decently understood
- lots of (multidimensional, subtle > massive) **inter-individual variation**
- understudied (but presumably pervasive) **between-group variation**
- patterned within- and **between-languages diversity**
- decent amouns of **data** (WCS, English-language naming…)
- good **models**…

ICREA · Universitat de Barcelona · UBICS · Agencia Estatal de Investigación · DDL Laboratoire Dynamique du Langage · Université Lumière Lyon 2 · Université de Lyon · NWO