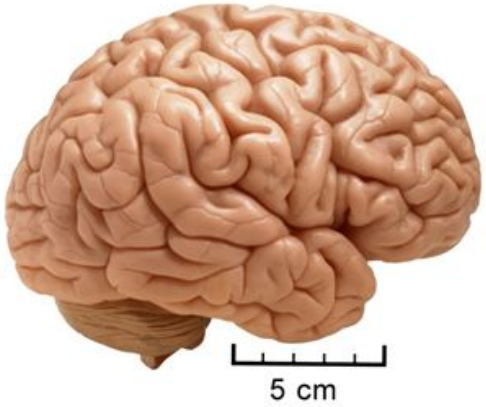
Color Categories in Monkeys

Daniel Garside

Colour Group (GB) - January Vision Meeting

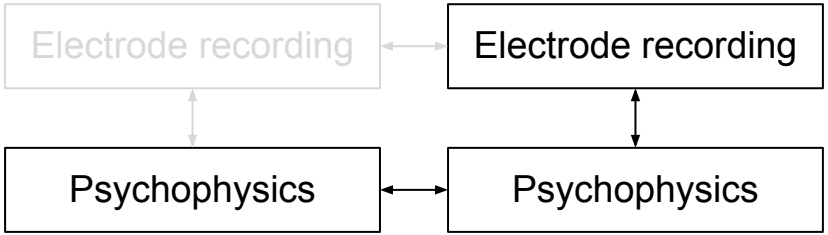
5th Jan 2022

Human vs macaque



Human

Rhesus macaque



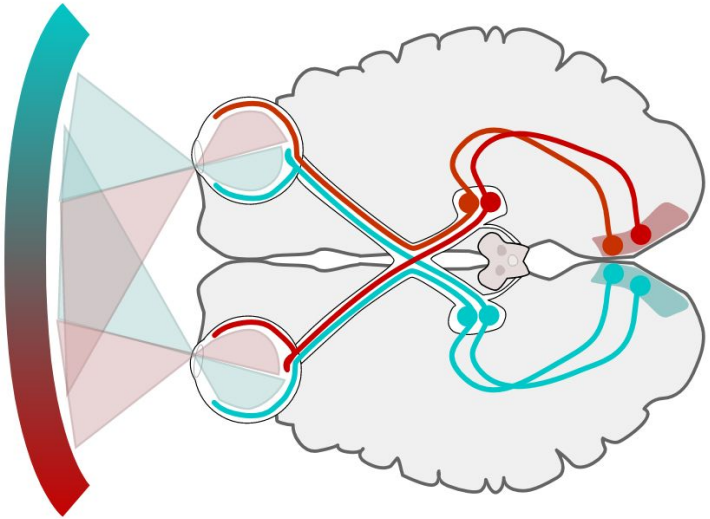
Different levels of color

Receptoral

Post-receptoral

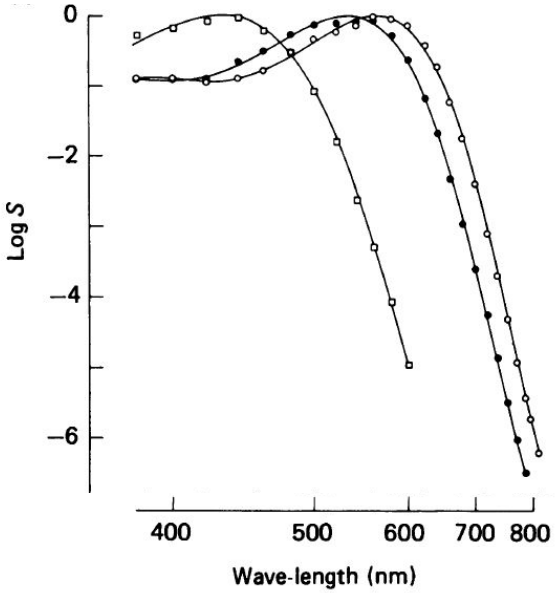
V1

Extra-striate



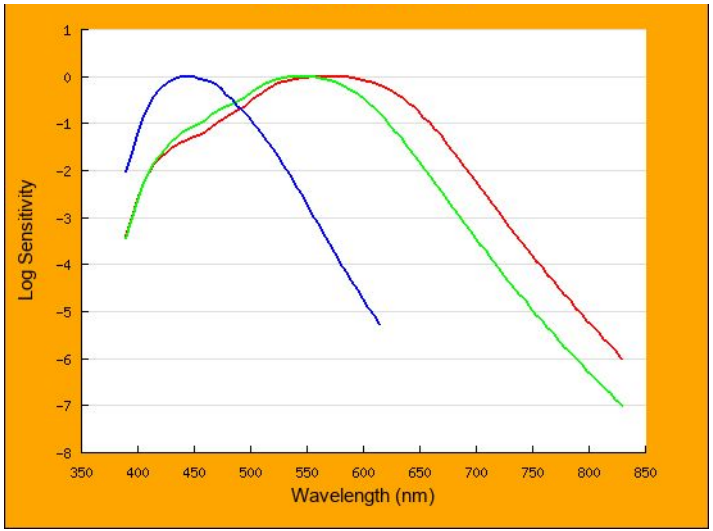
Receptoral

Macaque



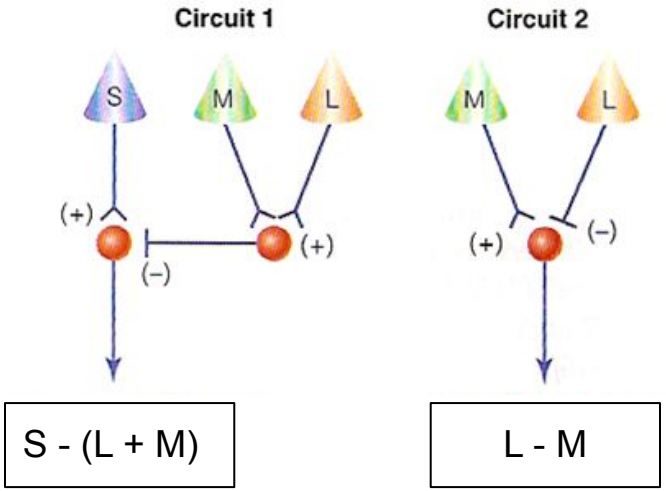
Baylor (1987)

Human



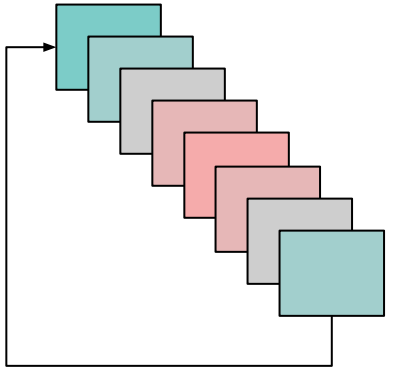
Stockman & Sharpe (2000)

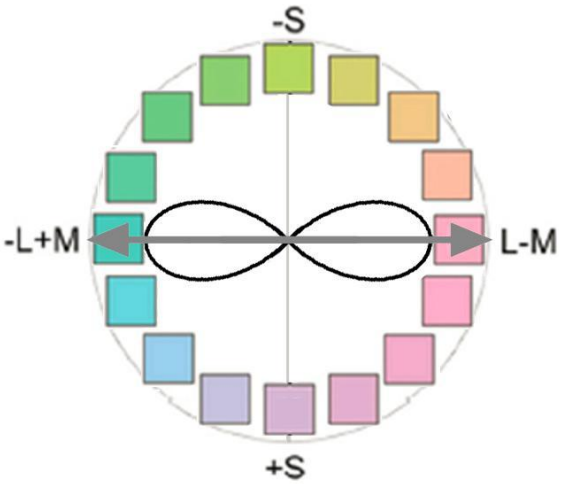
Post-receptoral



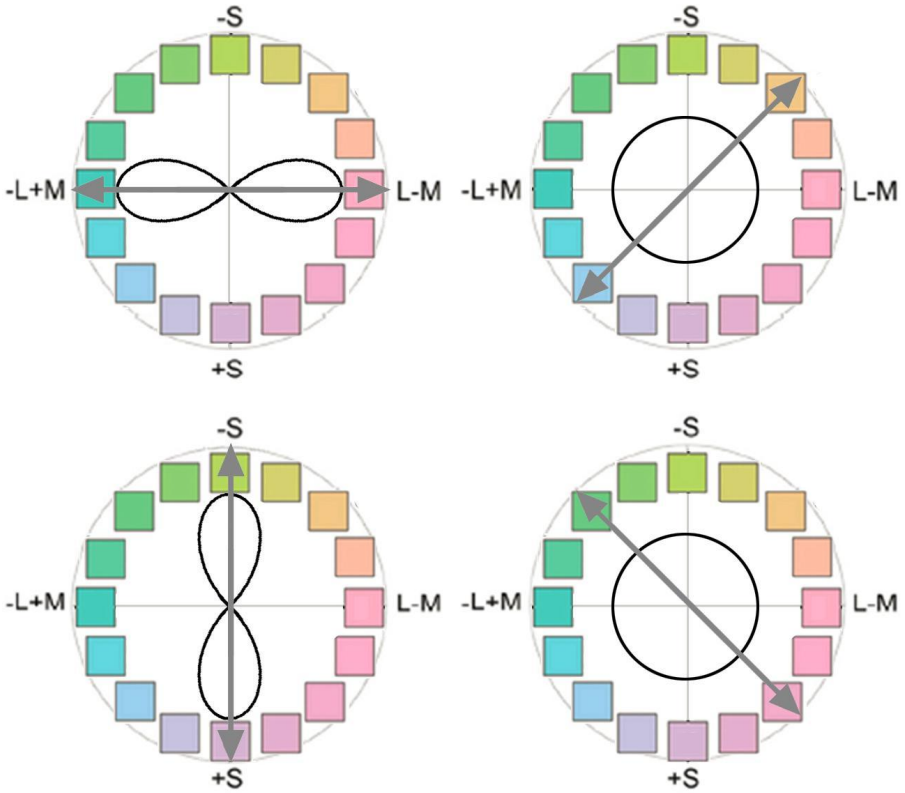
Prediction

If there is a neural mechanism selective for the adaptation colors
□ increased detection thresholds for those colors

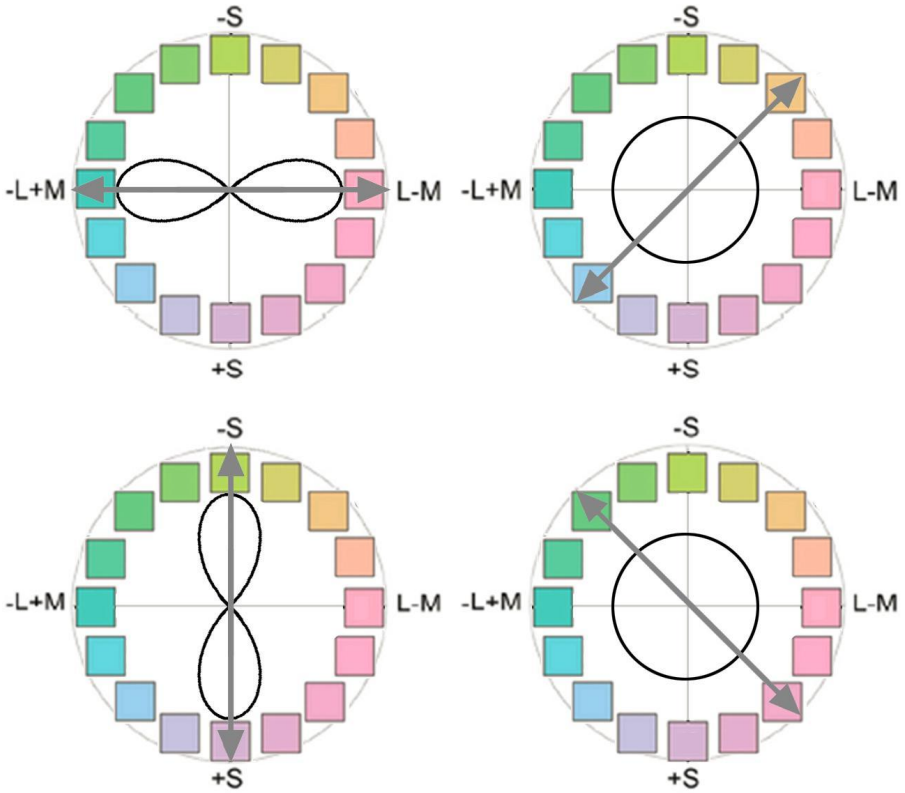




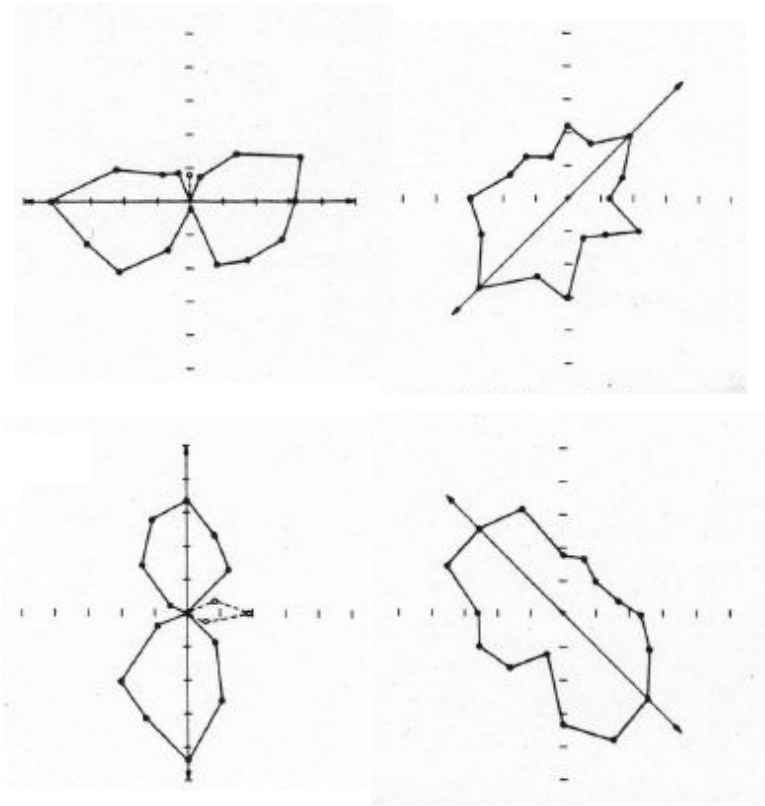
Standard Model, predicted changes in detection threshold



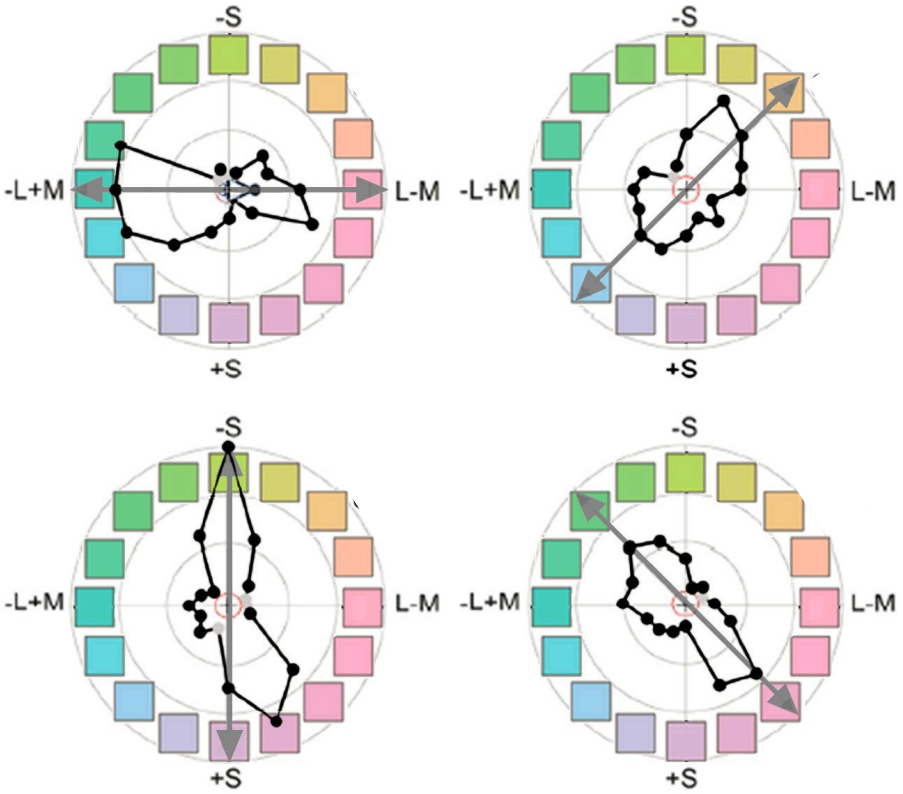
Standard Model, predicted changes in detection threshold



Human data - Krauskopf (1982)

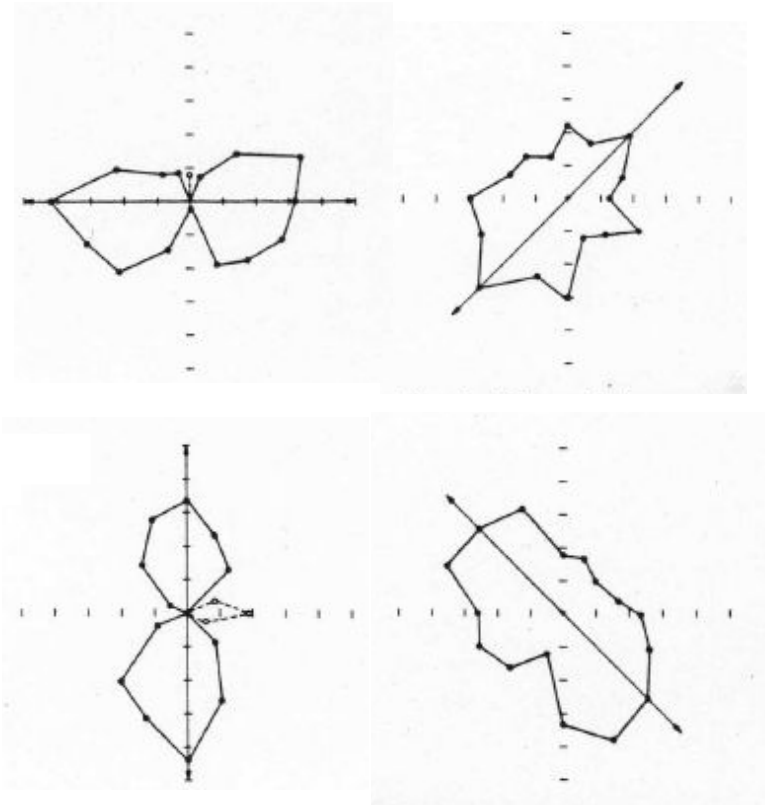


Standard Model, predicted changes in detection threshold

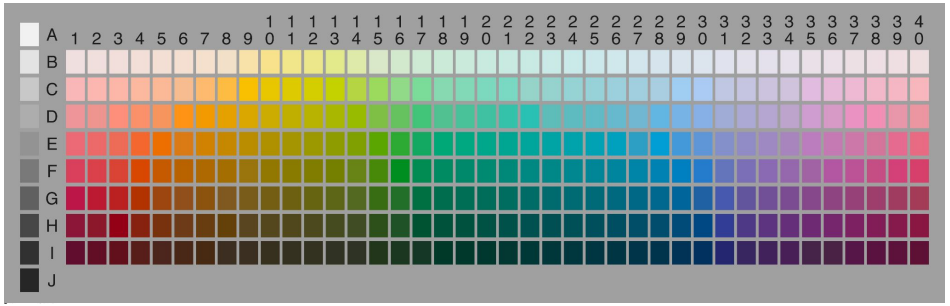


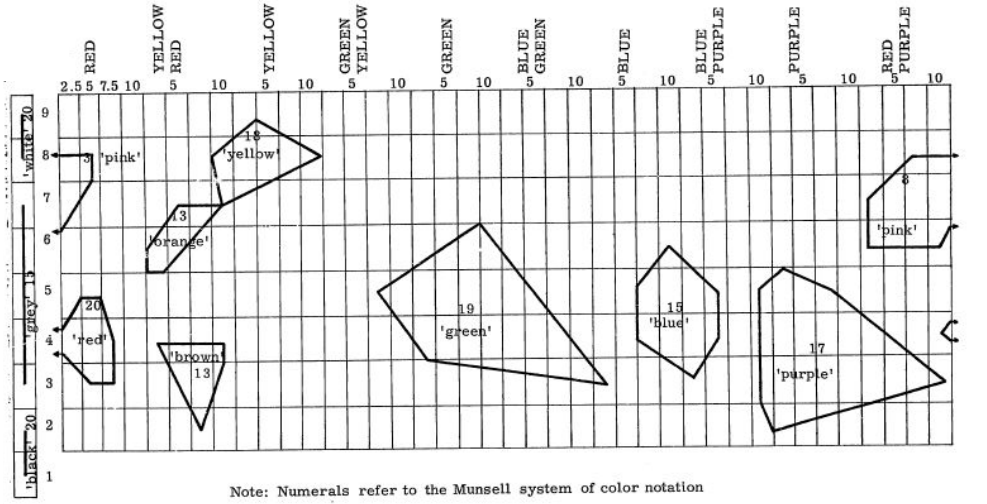
Stoughton et al. (2012) J Neurosci
Gagin et al. (2014) J. Vision

Human data - Krauskopf (1982)



Verbal tests





Berlin and Kay (1969)

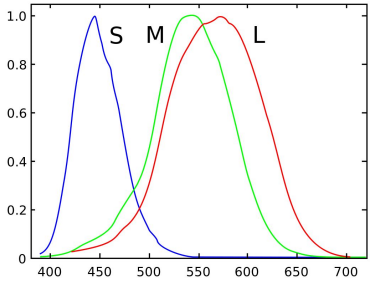
Theories of Color Categorization

Learned factors

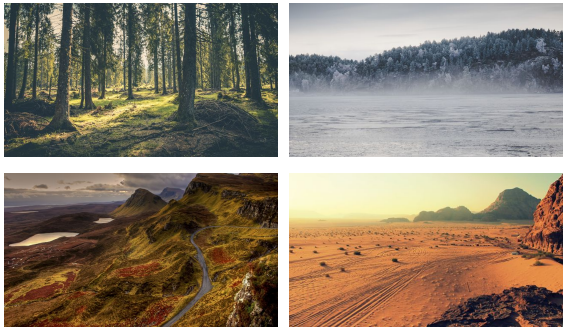
Verbal communication of color

Valero Doval for colornaming.net

Innate factors

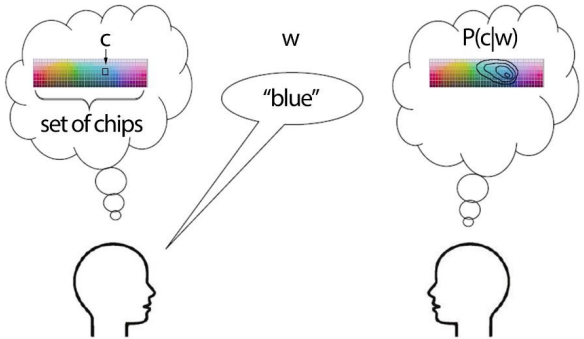


Cone spectral absorption functions



Color statistics of natural scenes

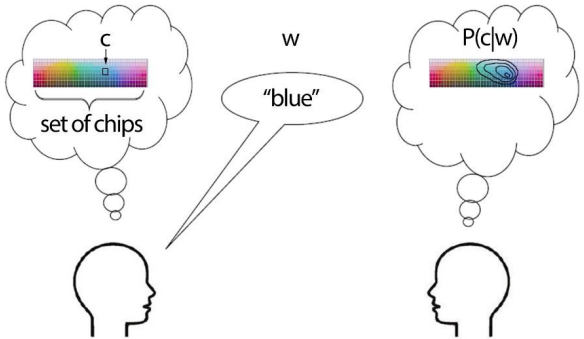
I pick a specific color chip and use a word to describe it



Gibson et al, *PNAS* 2017

I pick a specific color chip and use a word to describe it

How many guesses do you need to figure out the color?



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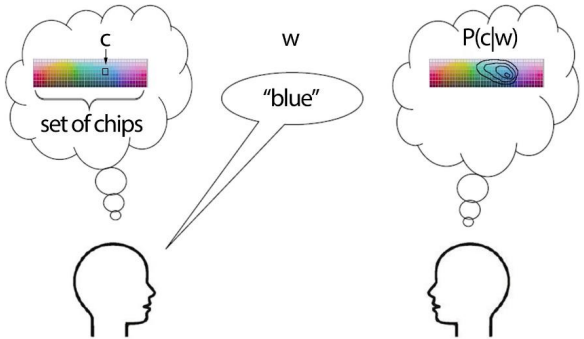


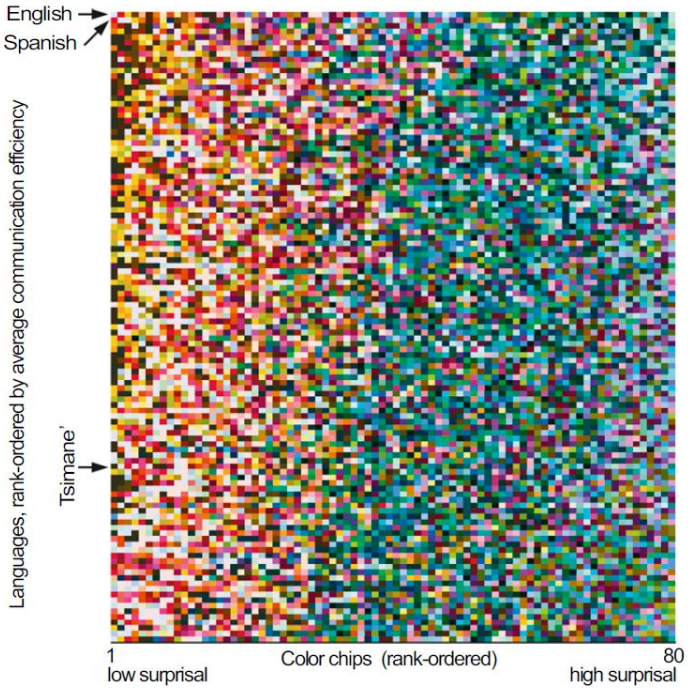
$$S(c) = \sum_{w} P(w|c) \log \frac{1}{P(c|w)}$$

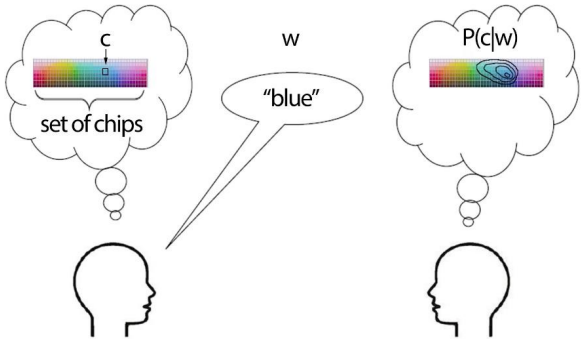
Gibson et al, *PNAS* 2017

All languages show higher communicative efficiency for warm over cool colors

I pick a specific color chip and use a word to describe it

How many guesses do you need to figure out the color?





$$S(c) = \sum_{w} P(w|c) \log \frac{1}{P(c|w)}$$

Gibson et al, *PNAS* 2017

Colors of objects are not arbitrary

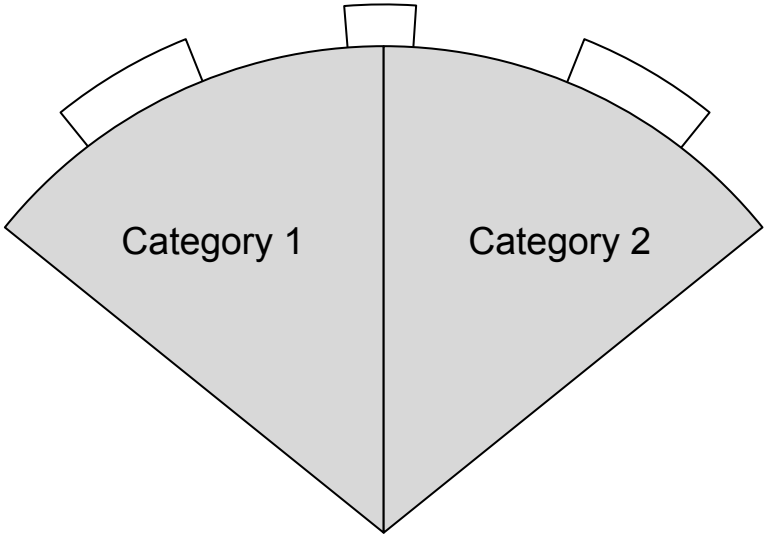
objects

backgrounds

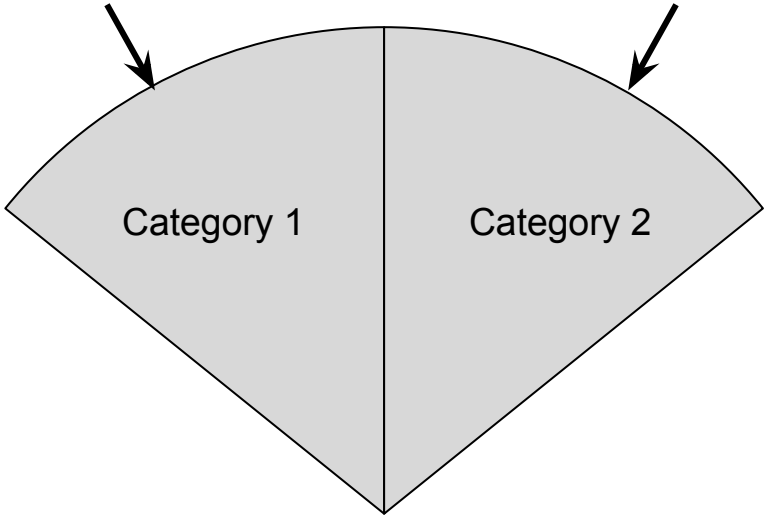
Rosenthal, Ratnasingham, et al, *Journal of Vision* 2018

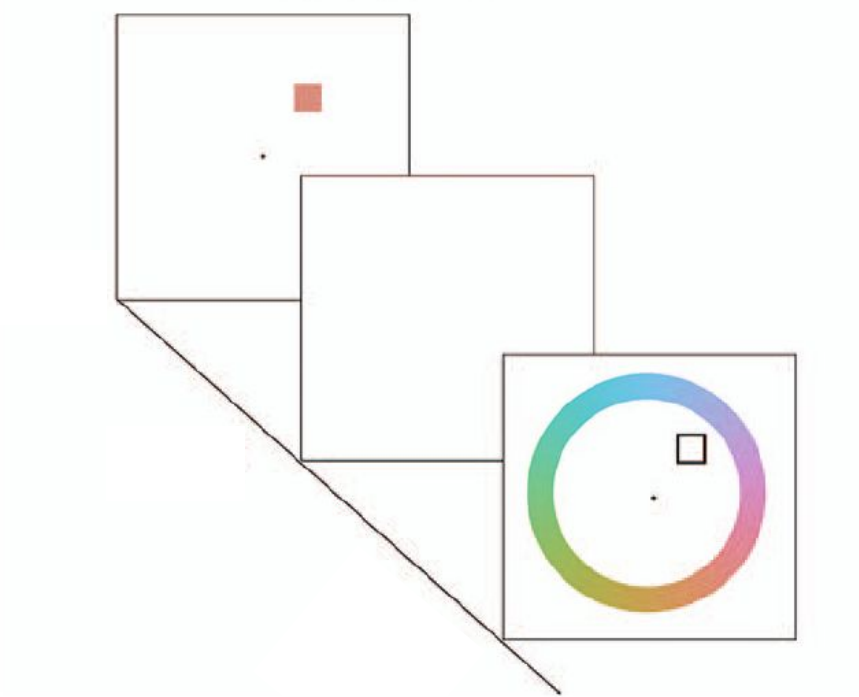
Signatures of categorical behavior

Smaller discrimination thresholds across category borders

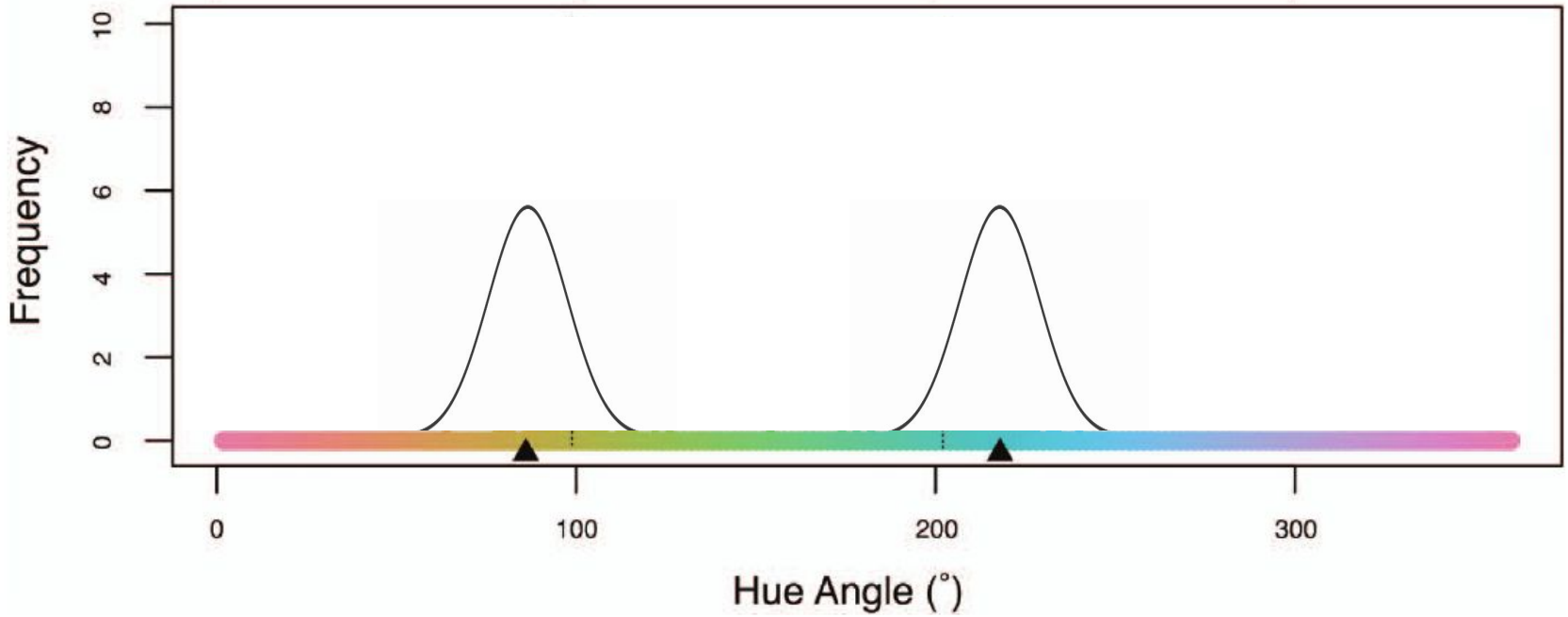


Bias towards best exemplar of category (“focal color”)

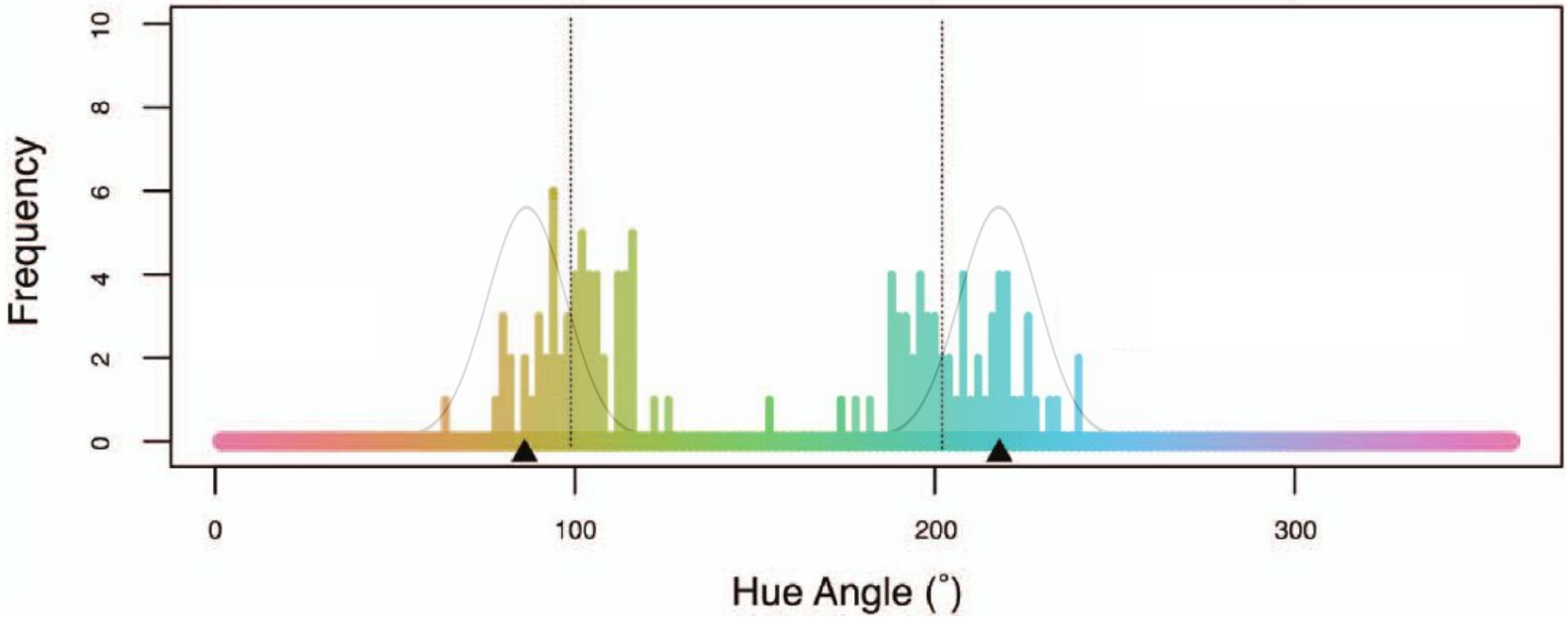




Bae et al. (2015) JEP:G



Bae et al. (2015) JEP:G



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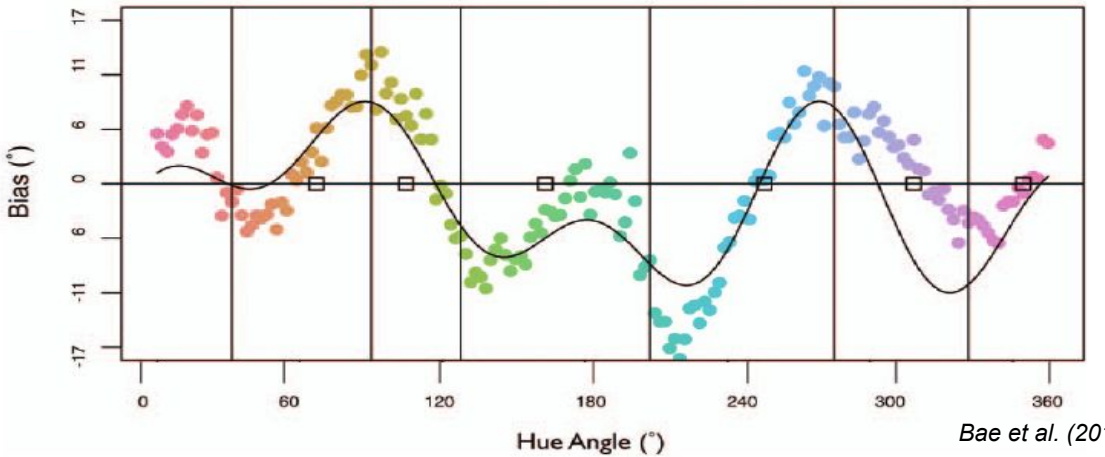

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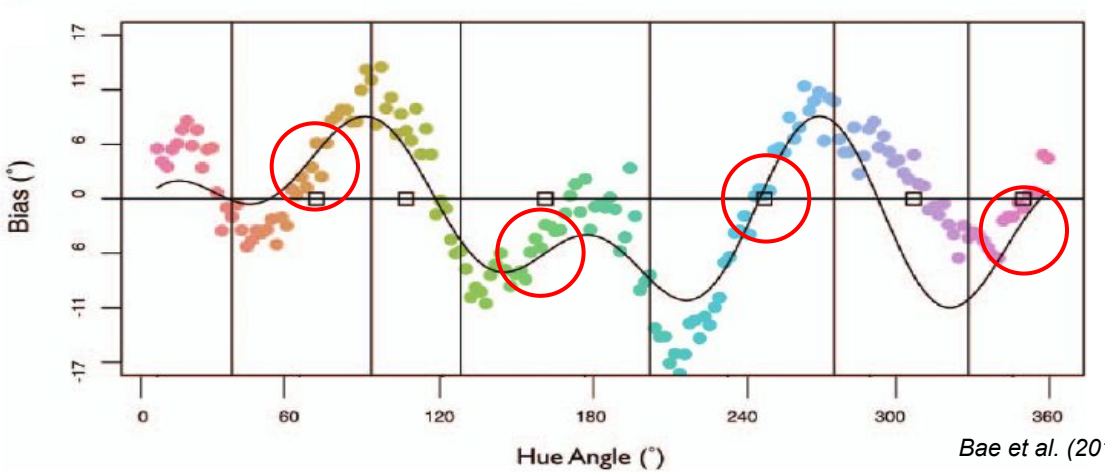
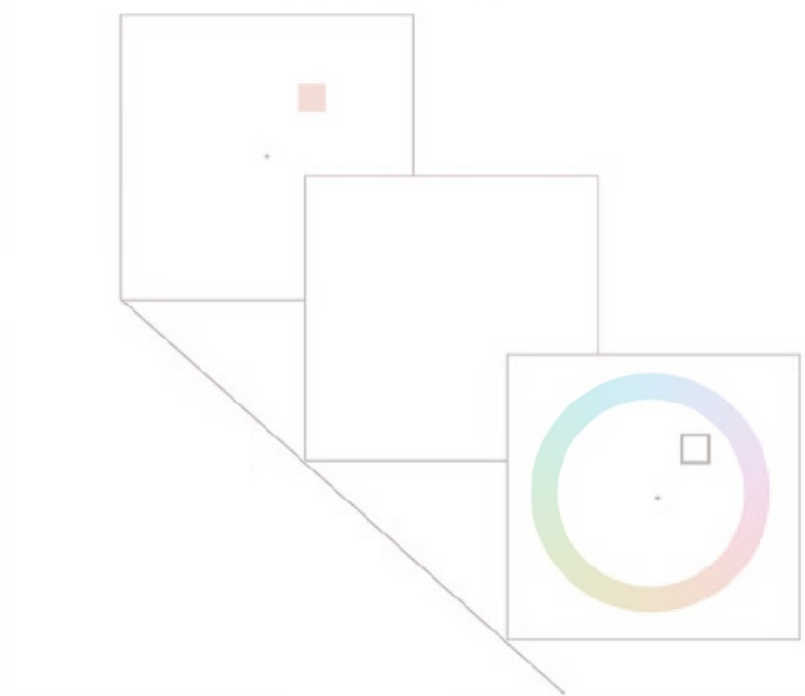
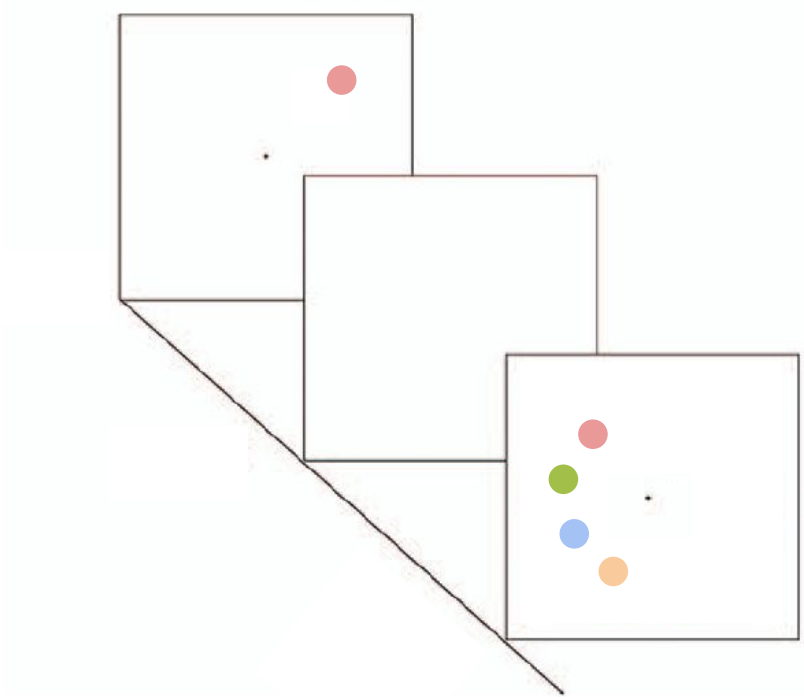


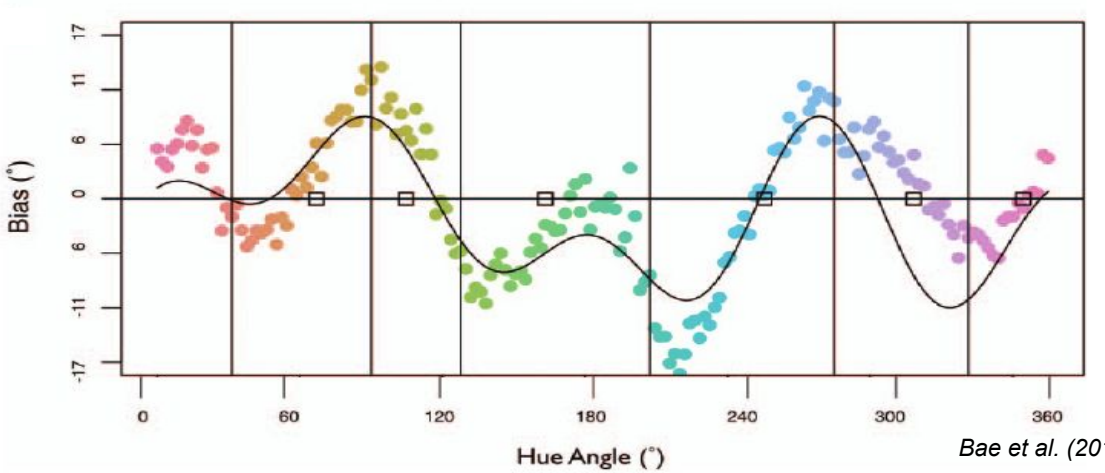
Attractor points

Bae et al. (2015) JEP:G

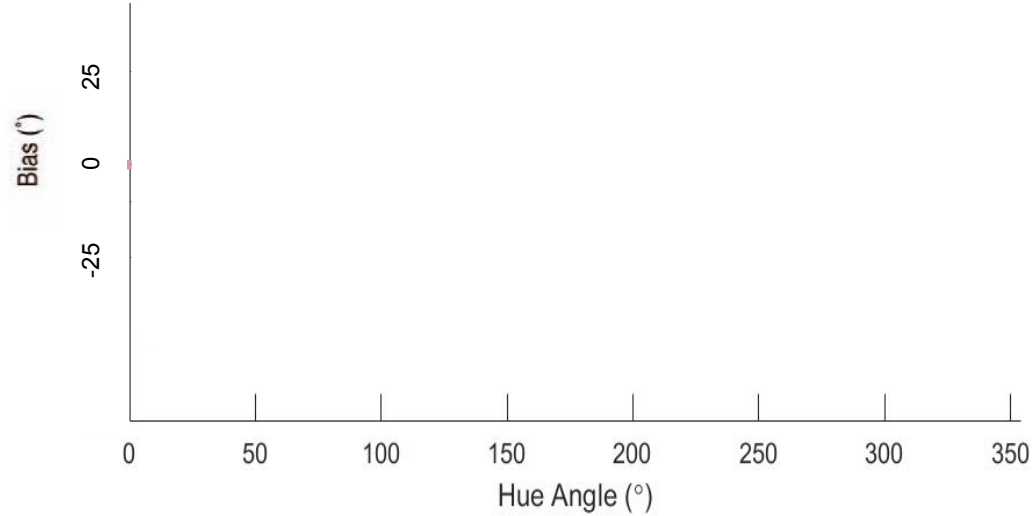


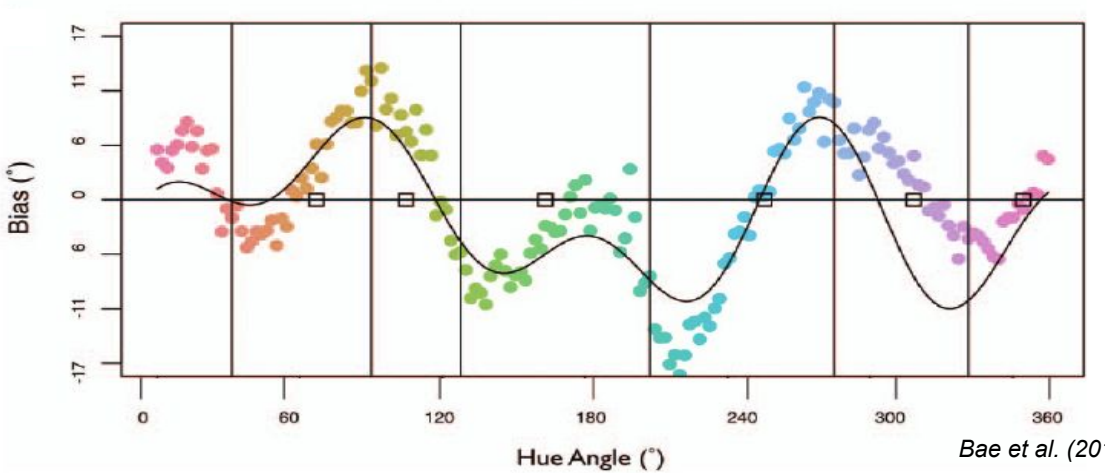


Bae et al. (2015) JEP:G



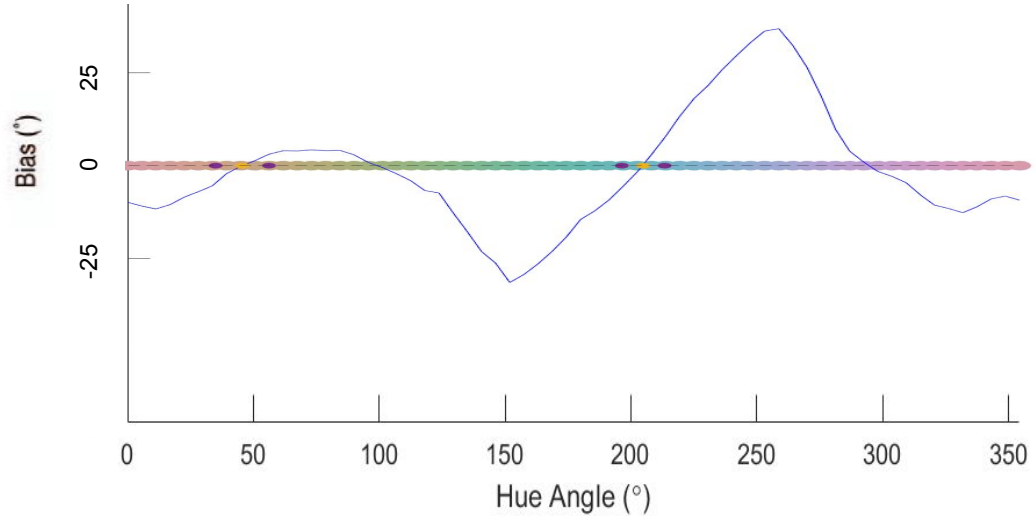
Bae et al. (2015) JEP:G





Bae et al. (2015) JEP:G

M1



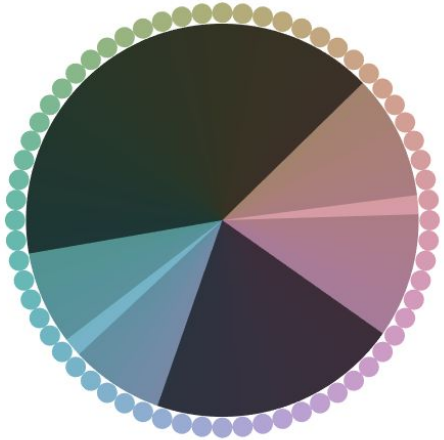
Locations of categories

M1

Locations of categories

M1

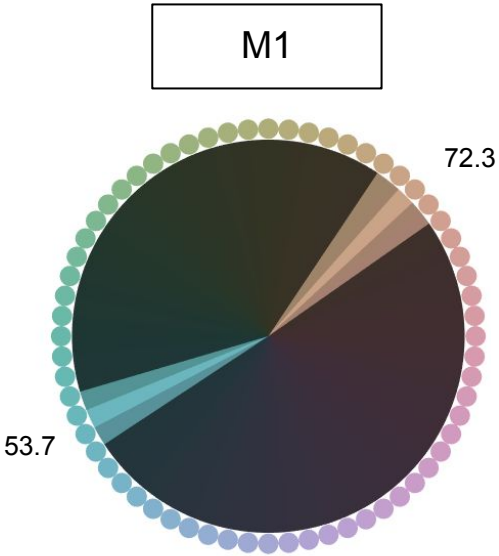
M2

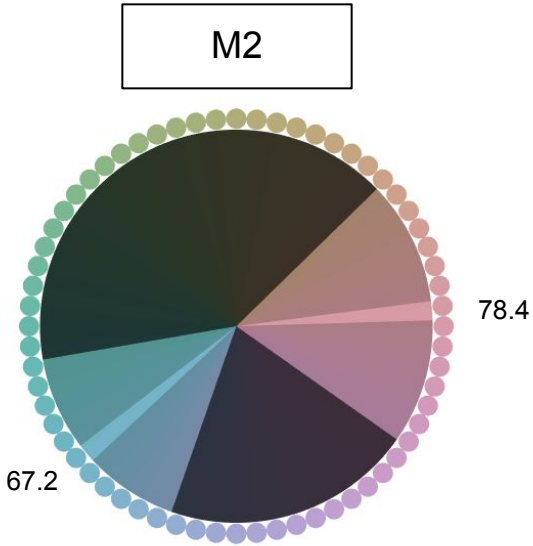


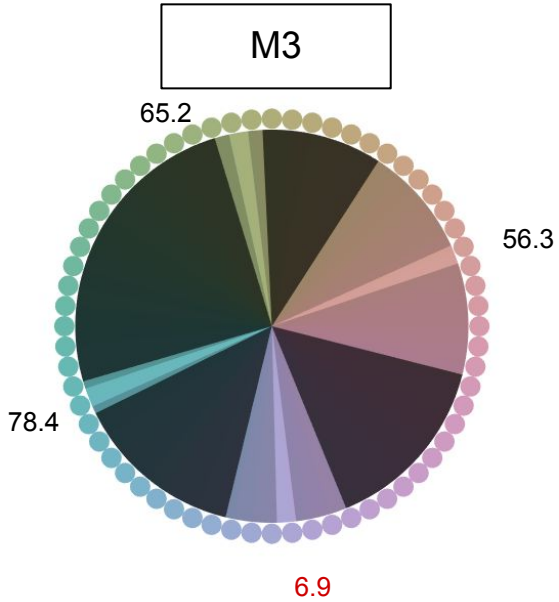
M3

Locations of categories

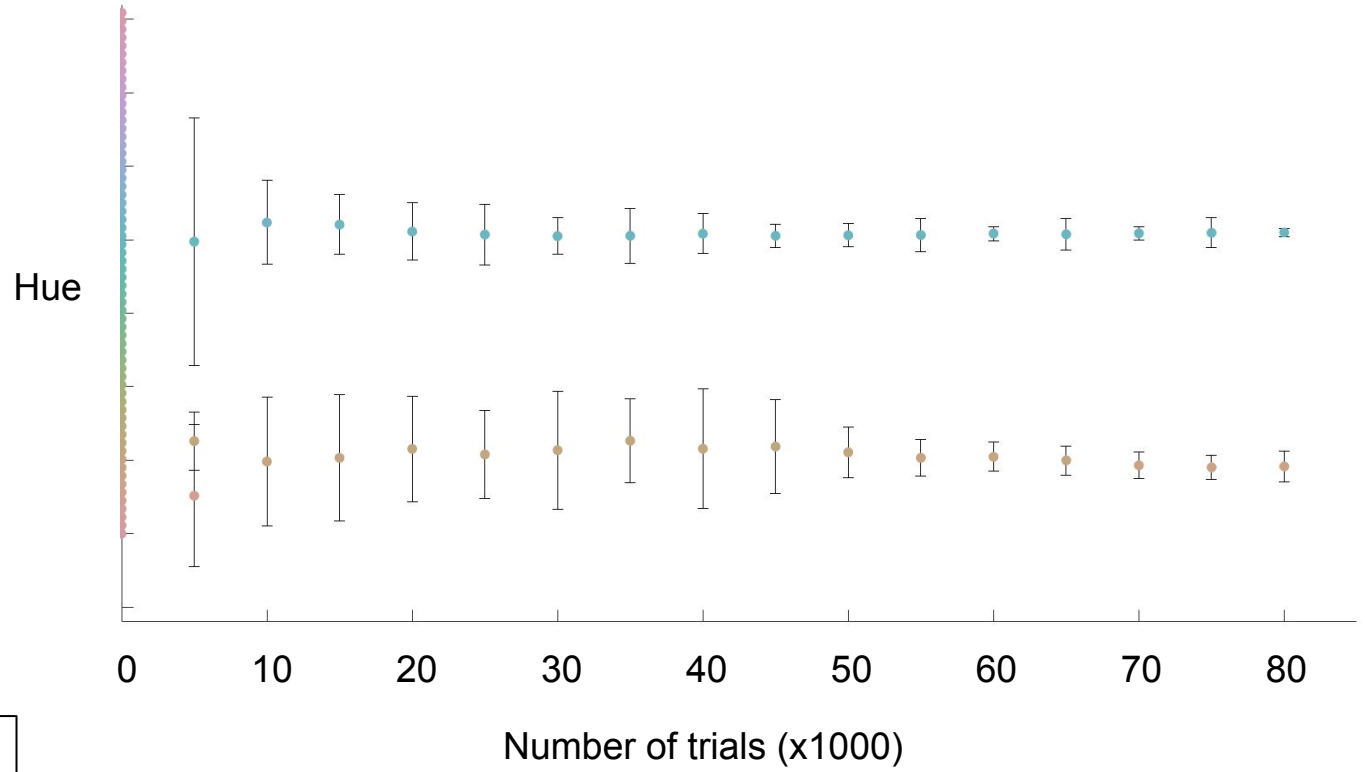
Category gradient values: a measure of attractor strength (range: 0 - 90)







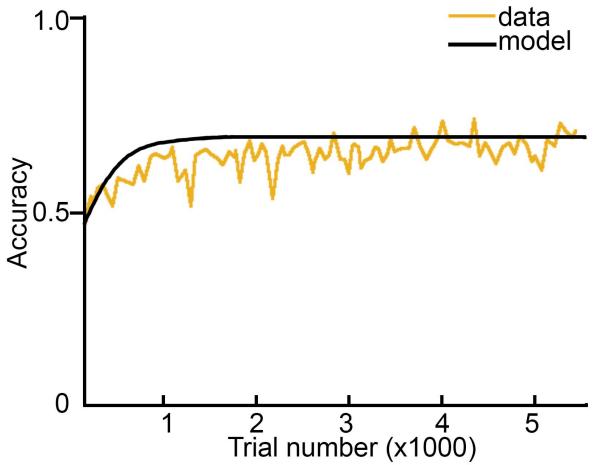
Power analysis



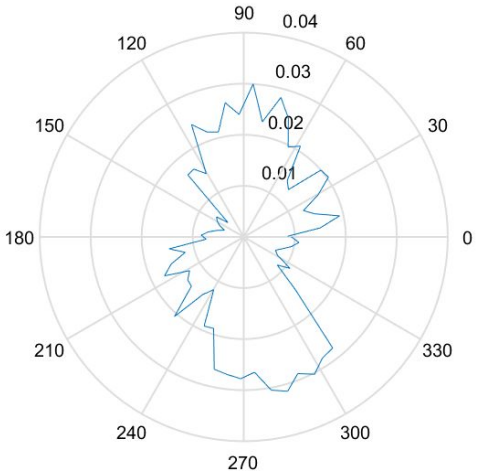
M1

Learning rates

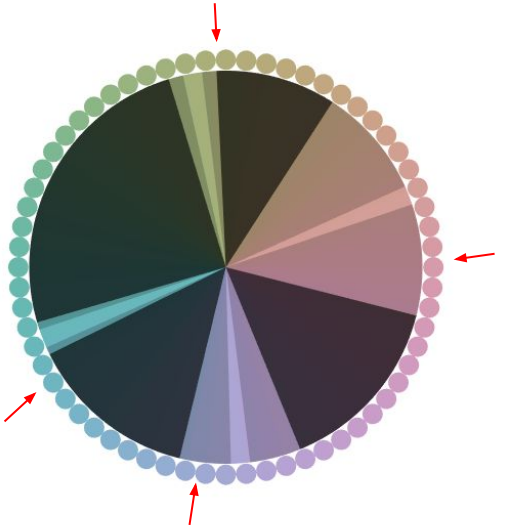
Learning rate
for a **single hue**



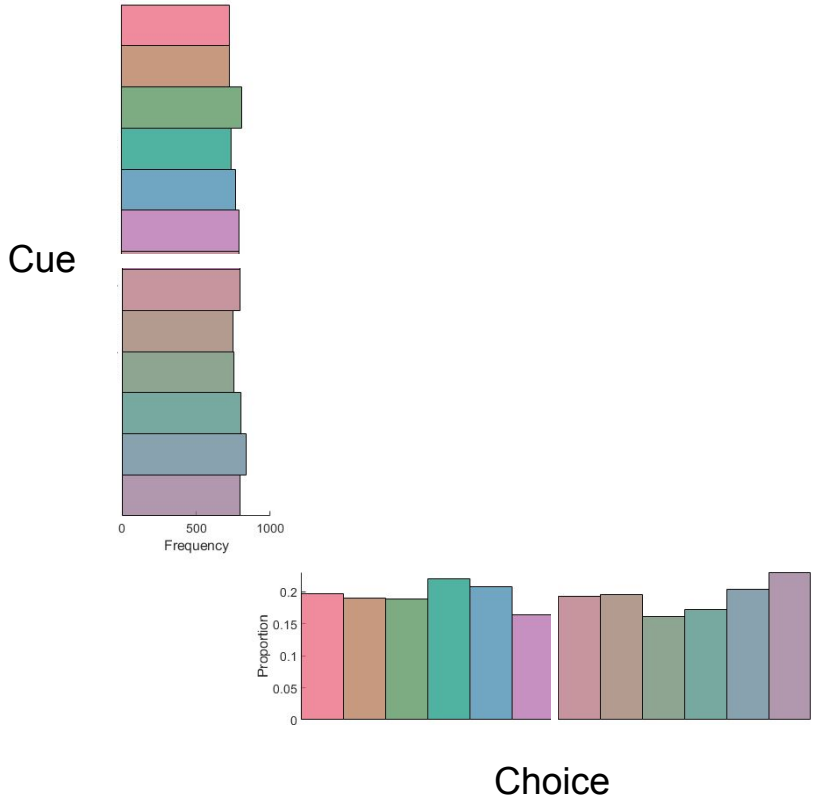
Learning rates
as a **function of hue**



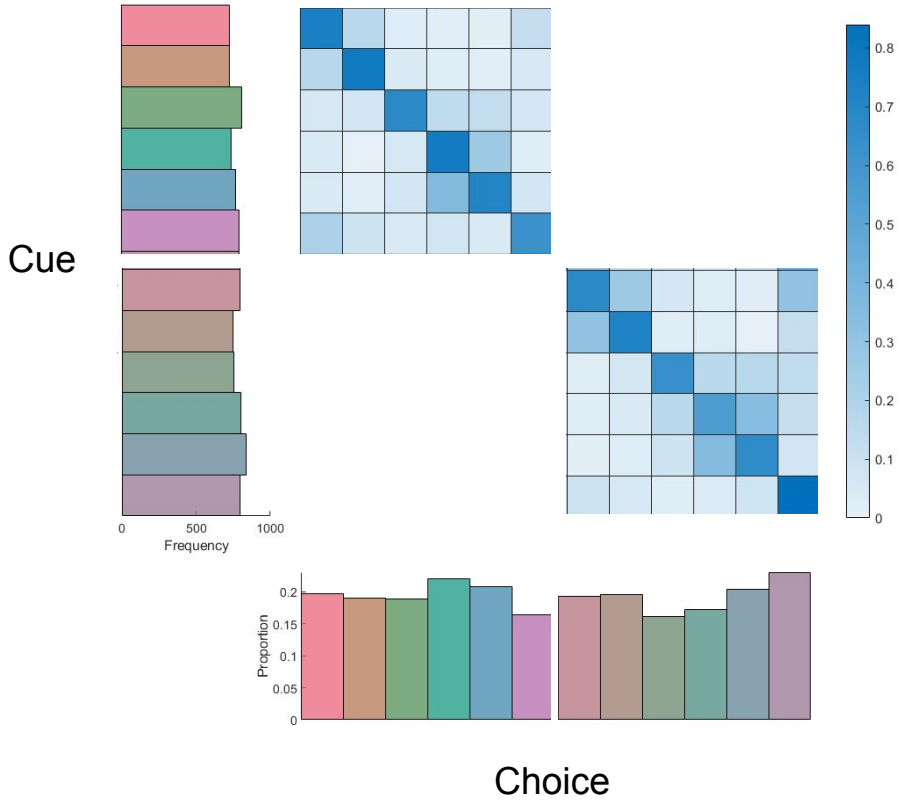
DKL axis directions



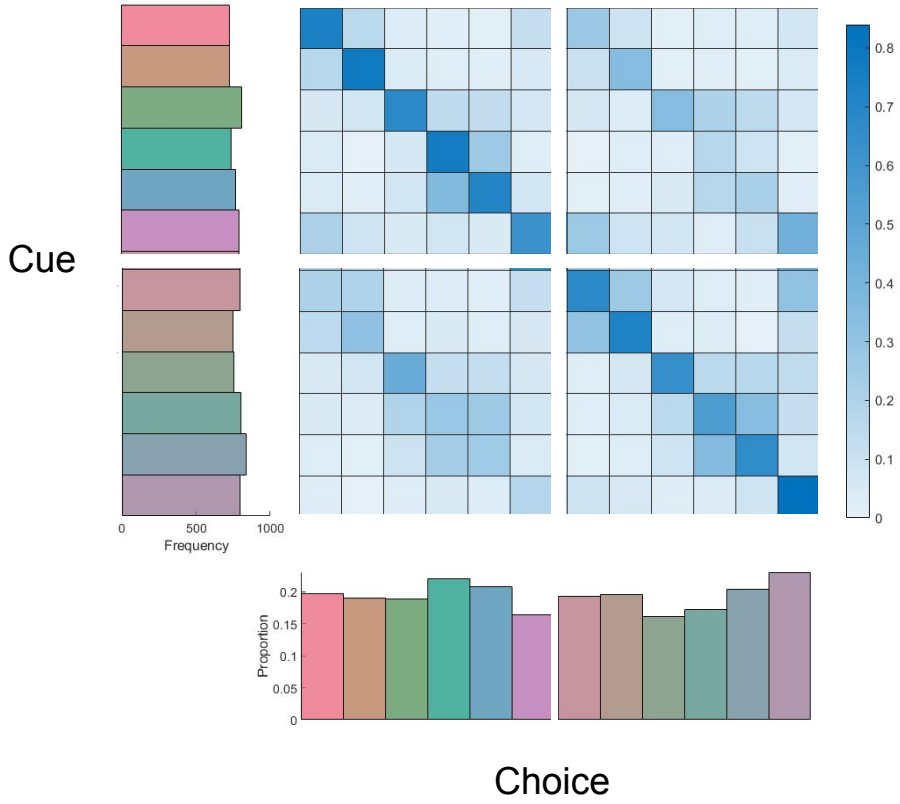
Multiple-satuation data heatmaps

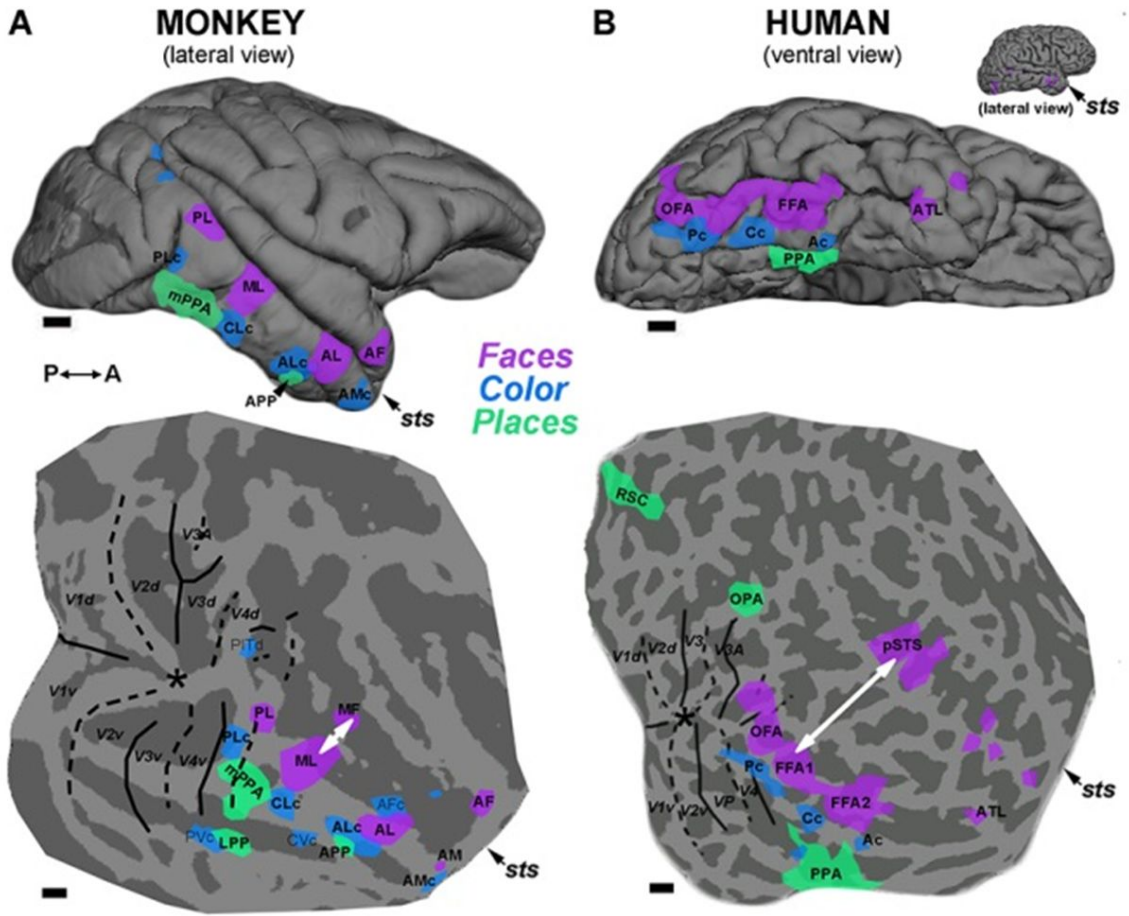


Multiple-satuation data heatmaps



Multiple-satuation data heatmaps





Lafer-Sousa, Conway*, Kanwisher*, *J Neurosci*, 2016

Conclusions

1. There are two color categories that are common to all 3 monkeys
2. These color categories correspond to the human distinction of warm and cool
3. The underlying template for the fundamental structure of color categories for trichromatic primates appears universal, potentially determined by the color statistics of relevant parts of scenes (objects)

Acknowledgements

Bevil Conway

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Whitney Teagle
Riley Hoffman

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Thank you!

Intramural Research Program

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MANY PEOPLE,
INFINITE POSSIBILITIES

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