A Probabilistic Model of the Categorical Association between Colors

Jason Chuang (Stanford University)
Maureen Stone (StoneSoup Consulting)
Pat Hanrahan (Stanford University)

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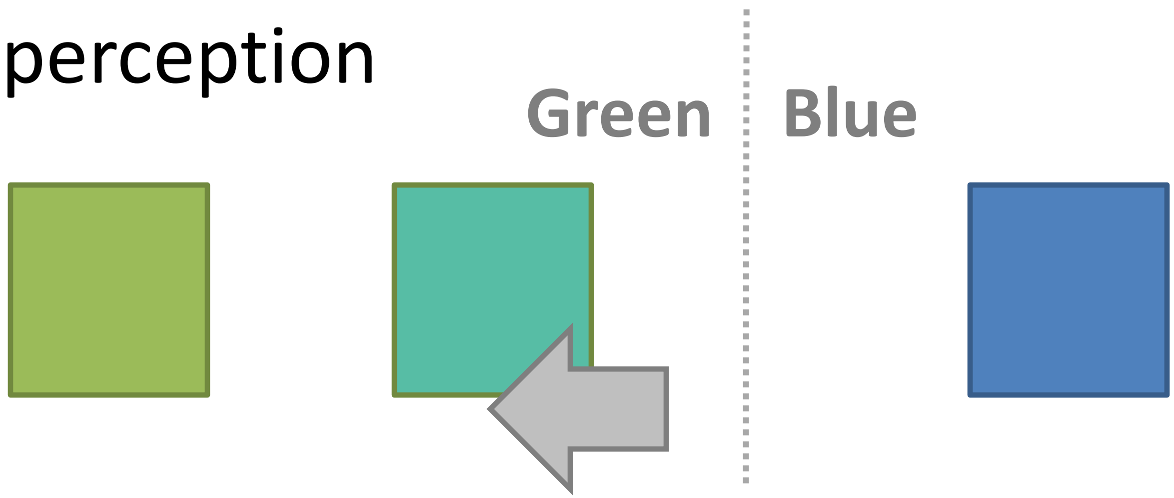
Overview

- **Introduction**
  - **Color names**
  - **Previous work**
  - **Goals**
- Categorical association
  - Probabilistic framework
  - Results
- Summary

Why Color Names?

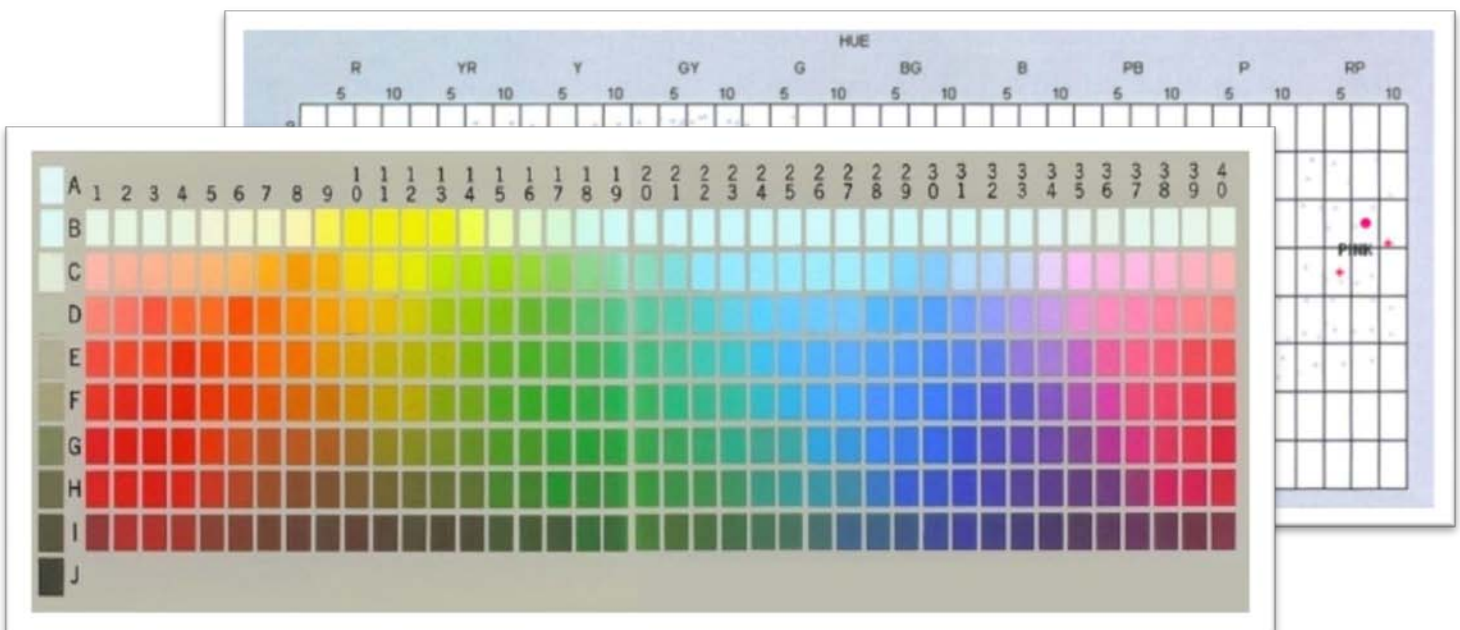
- Affect our perception



- Improve communication

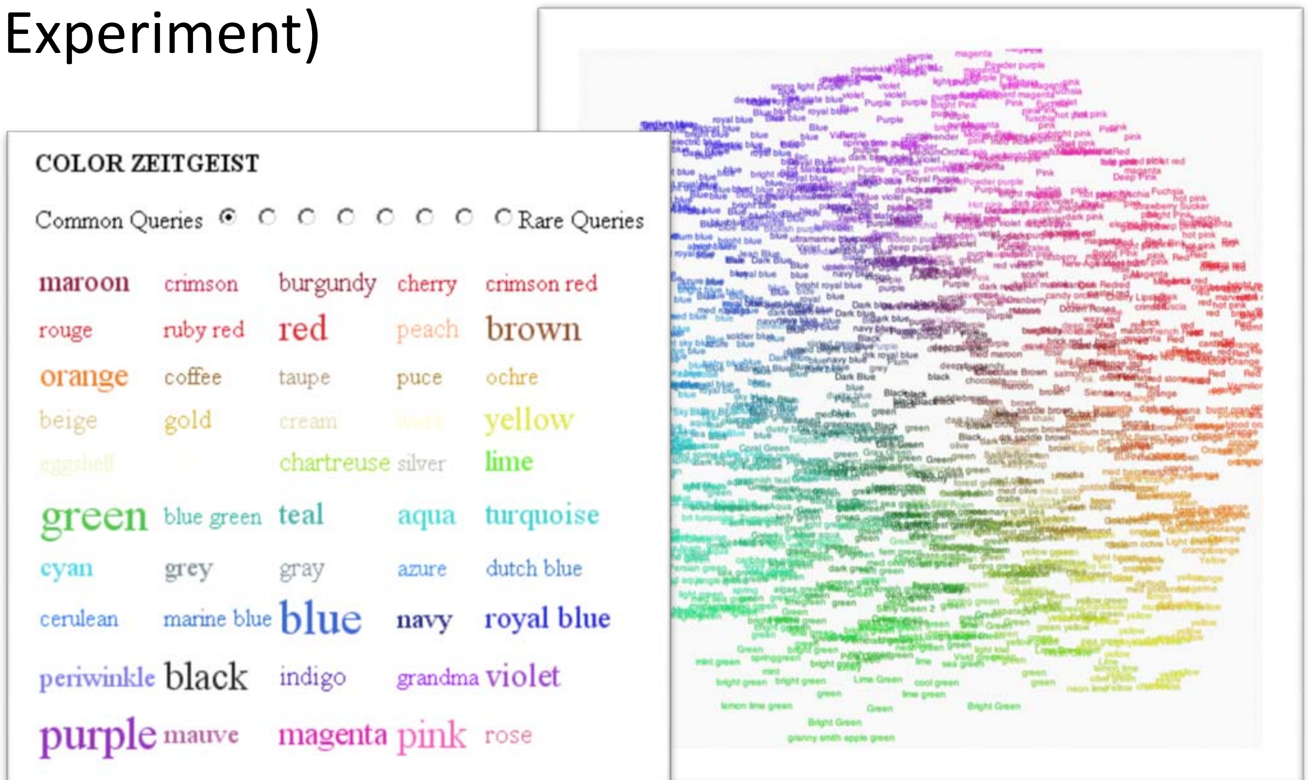
Naming Studies

- Earlier studies
  - For 19 languages, only 1 speaker (Berlin & Kay)
  - 10 speakers for English (Benavente)
  - 25-30 speakers for 110 languages (World Color Survey)

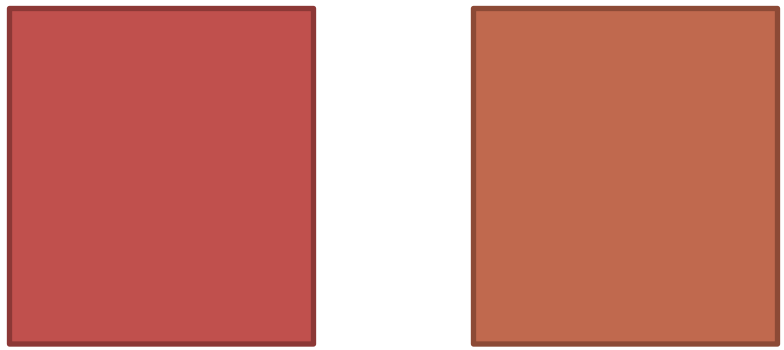


More Naming Data

- Online surveys
  - 238 speakers in English (Dolores Labs)
  - 4000 speakers in 20 languages (HP Naming Experiment)



Color Name Models

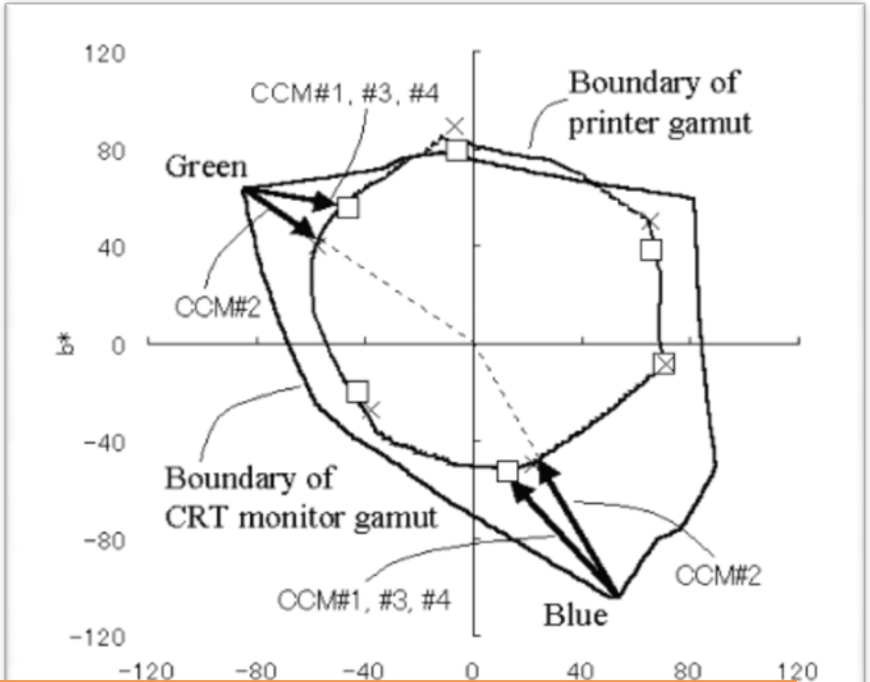


“Do two colors have the same name?”

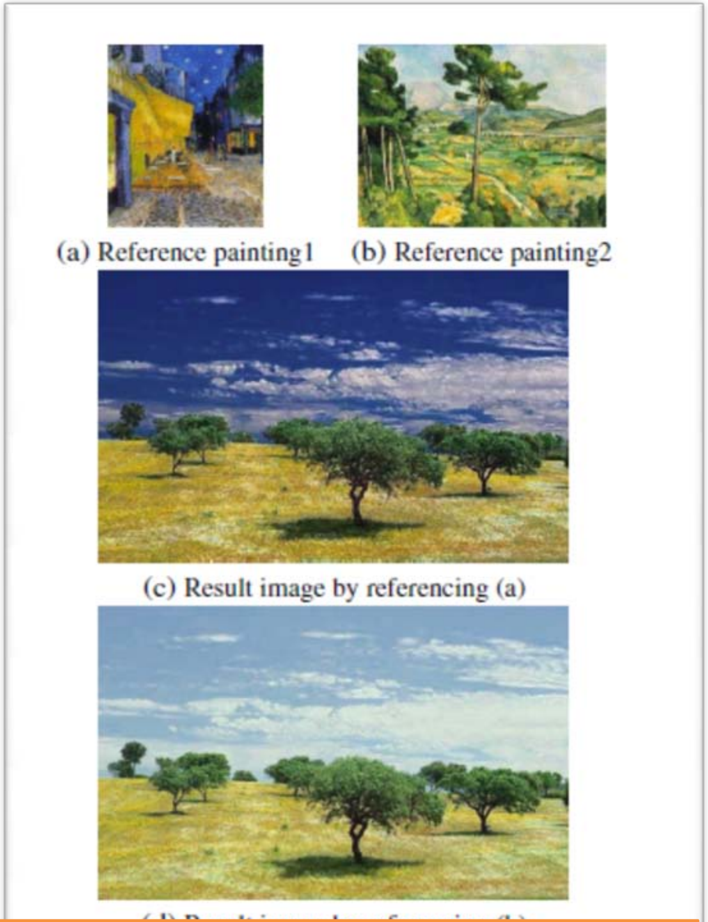
“Which color has a more consistent name?”

Color Name Models

- Preserving color names



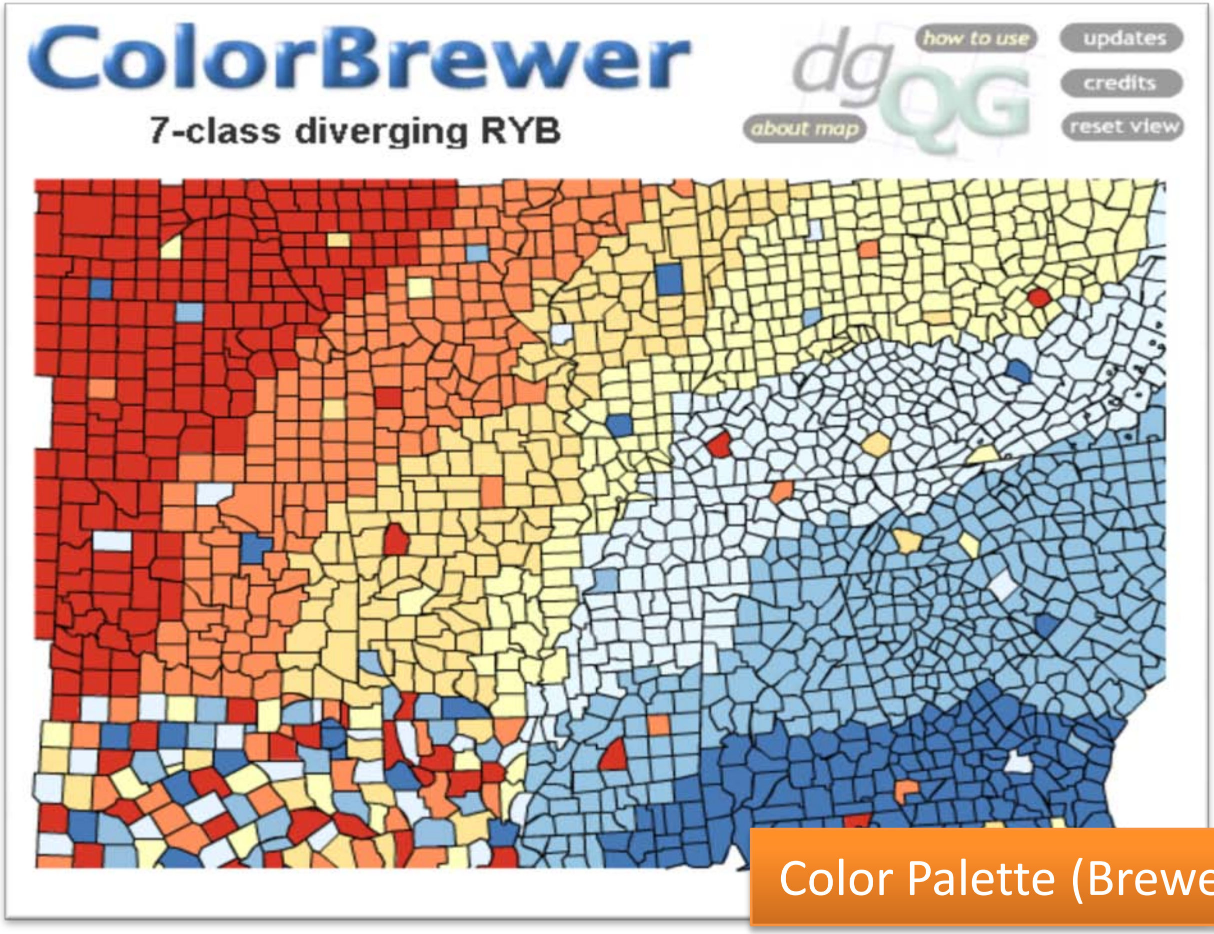
Gamut Mapping (Motomura 2001)



Color Transfer (Chang et al. 2003)

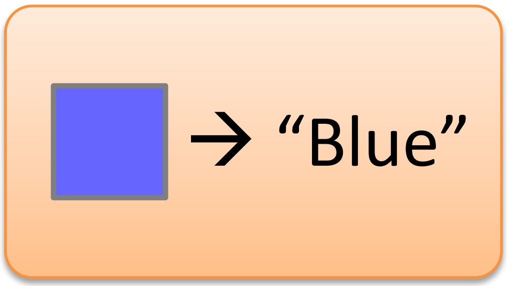
Color Name Models

- Colors with consistent names



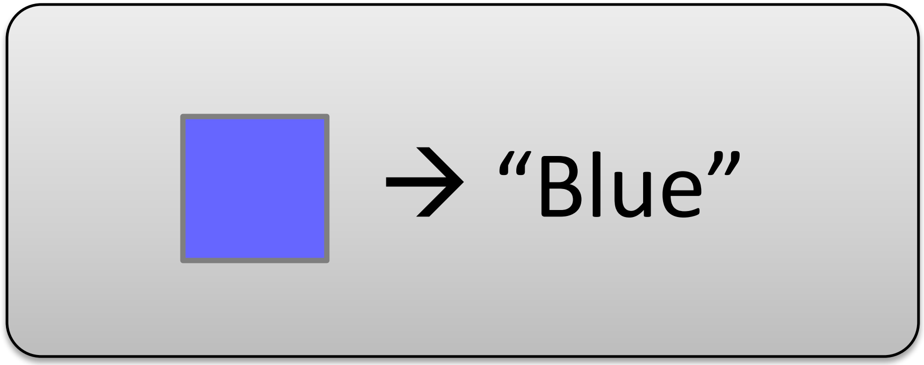
Color Palette (Brewer 1996)

Previous Work

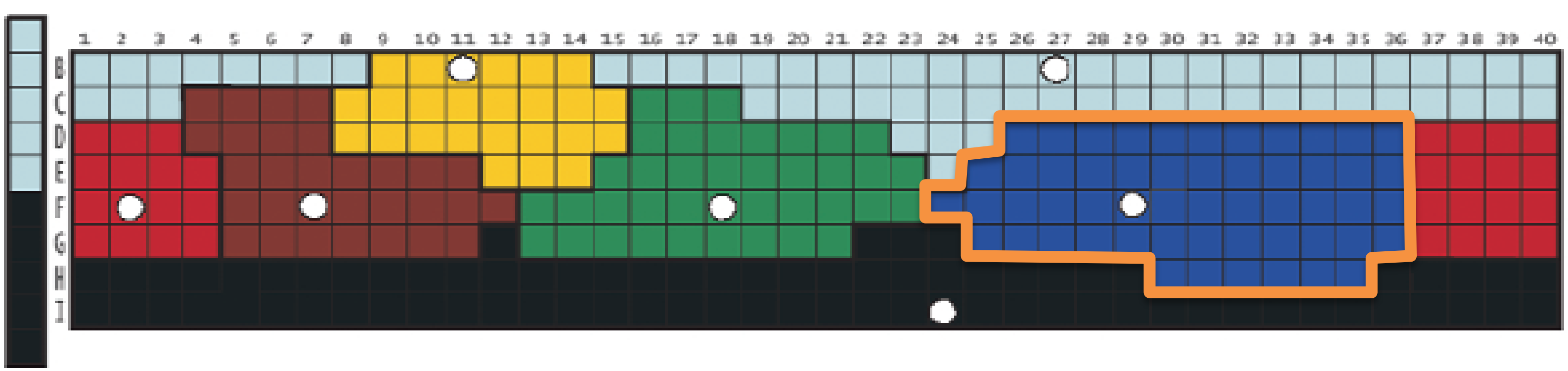


- **Single term**
  - **Focus plus boundary**
  - **Simple partitioning**
- Prototypes
  - Focus plus distribution
  - Linear combination of names
- Non-parametric models
  - Statistical representation
  - Requires sufficient data

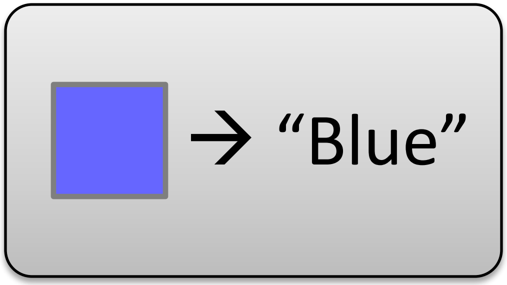
Single Terms

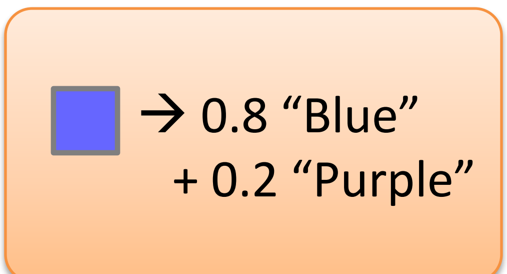


- Partition the color space into name regions
  - Illustrating basic color terms (Berlin & Kay 1969)
  - Lin et al. 2000, Chang et al. 2004, Kelly & Judd, …



Previous Work





- Single term
  - Focus plus boundary
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- **Prototypes**
  - **Focus plus distribution**
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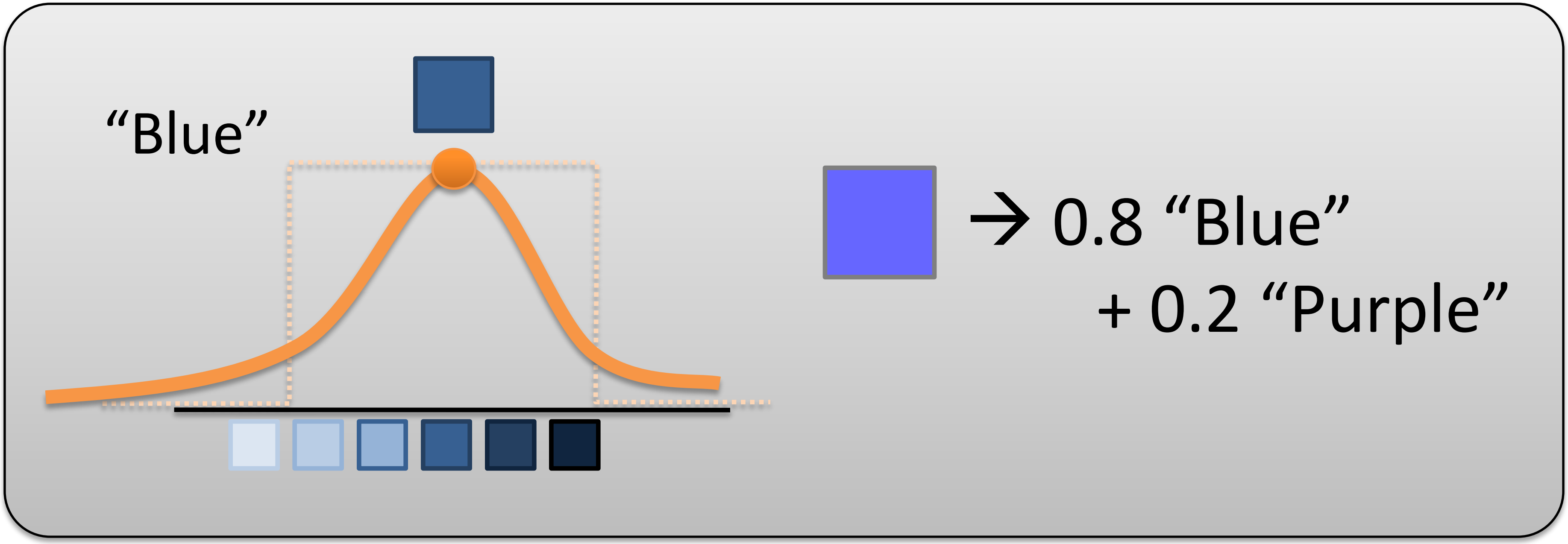
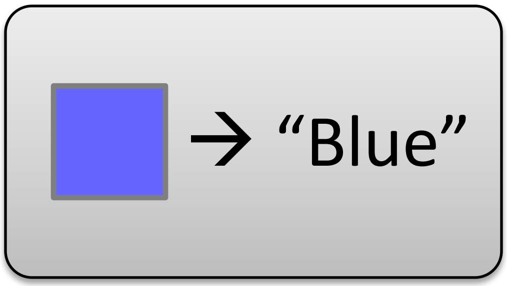
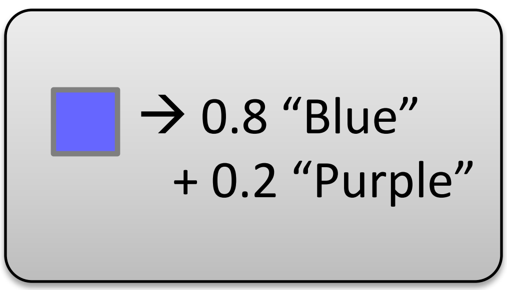
Prototypes

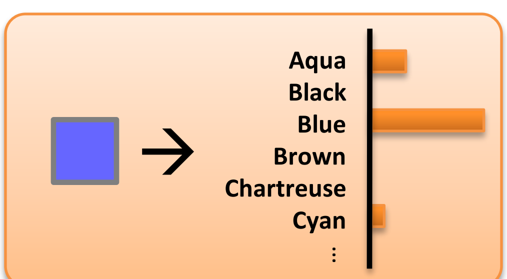


- Focus plus parameterized distribution
- Linear combination of a list of names
  - Gaussians (Motomura 2001)
  - Sigmoid-Gaussians (Benavente et al. 2002)

Previous Work

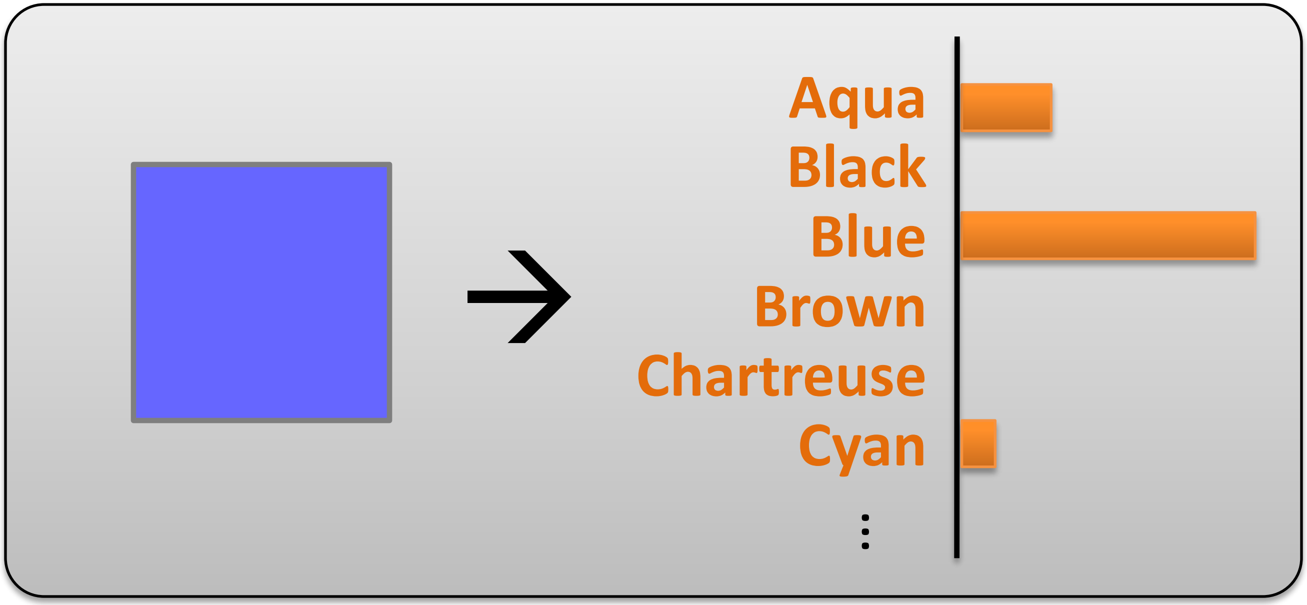






- Single term
  - Focus plus boundary
  - Simple partitioning
- Prototypes
  - Centroid plus distribution
  - Linear combination of names
- **Non-parametric models**
  - **Statistical representation**
  - **Requires sufficient data**

Non-Parametric Models



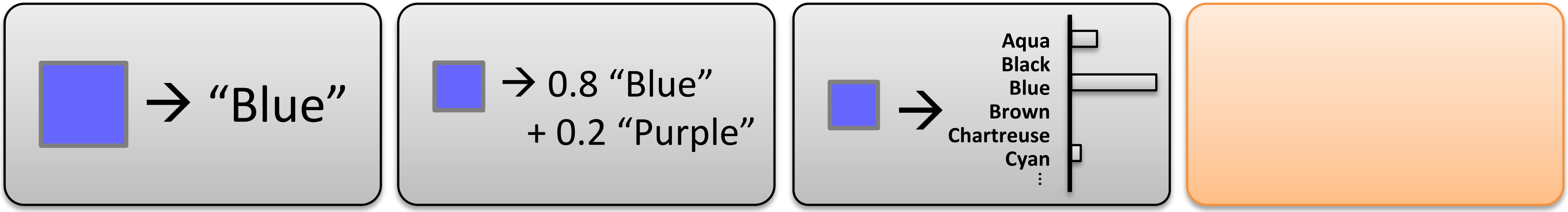
- Don’t assume particular distribution
- Represent each term by a histogram
  - Benavente et al. 2006
  - Moroney 2007

Issues

- Color name regions
  - Different shapes and sizes
  - Want to preserve detailed shapes of the region
- Color vocabulary
  - More than 11 basic color terms
  - Emerging terms, multilingual data
  - Want to determine important color words from data, instead of using a pre-determined list
  - Robust when rare words are included

Our Goals

- Non-parametric model
- Inclusion of all color words, possibly from multiple languages
- Support a rich set of computational tools



Overview

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  - **Probabilistic framework**
  - **Results**
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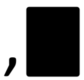
Categorical Association

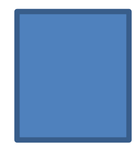
- **Notations**
  - **Colors and Words**
- Probabilistic Framework
  - “Examples” of colors
  - Color saliency
- Results
  - World Color Survey
  - DoloresLabs Dataset
  - Comparison

Notation

- Color naming data consists of two variables
  - Colors C = { , , , , ,  }
  - Words W = { “aqua”, “black”, “blue”, “brown”, “chartreuse”, “cyan”, … }

Relationships

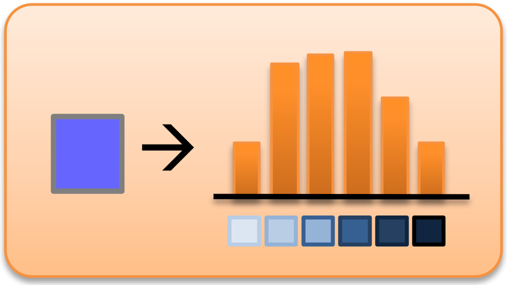
- Two types of relationships
  - Given a color , what are the likely words applied to the color?

$$P(W|C=\text{}$$  $$)$$

  - Give a word “blue”, what are the likely colors the word refers to?

$$P(C|W=\text{“blue”})$$

Categorical Association



- Notations
  - Colors and Words
- **Probabilistic Framework**
  - **“Example” colors**
  - **Color saliency**
- Results
  - World Color Survey
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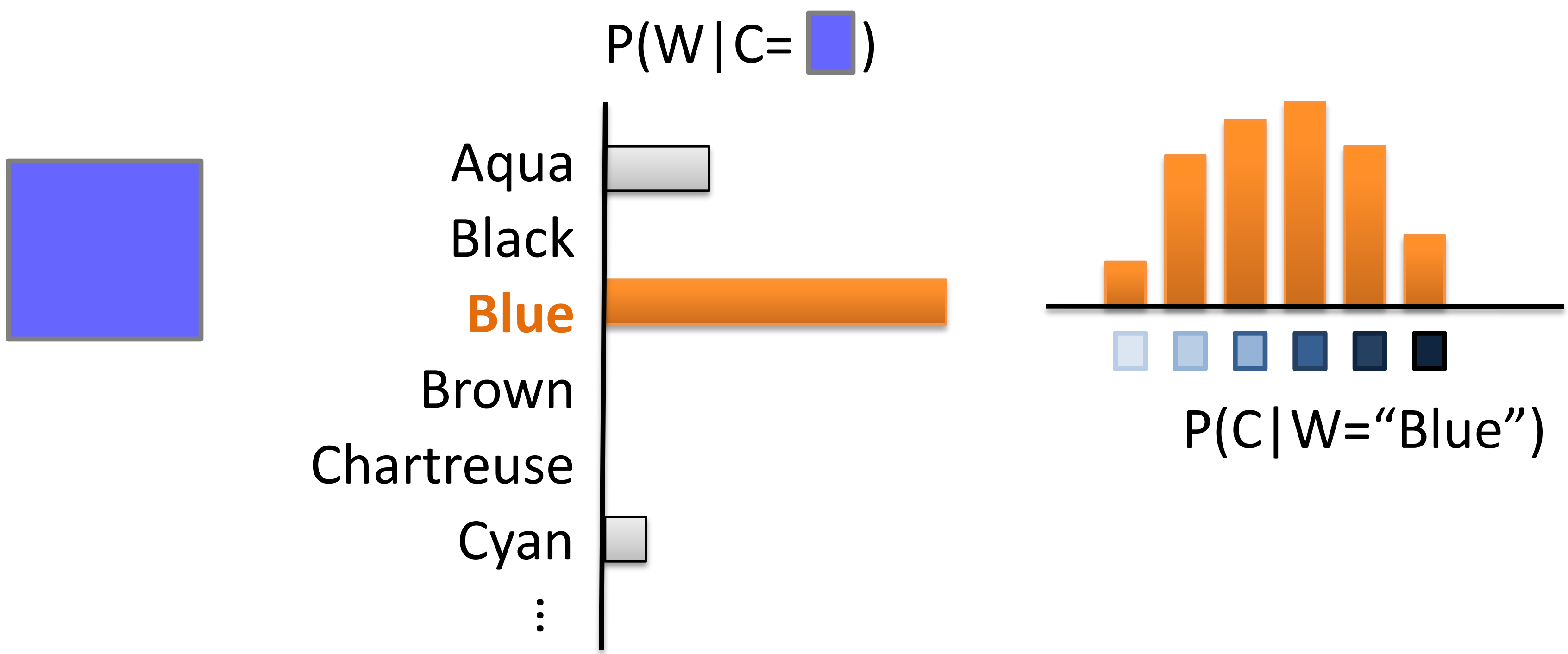
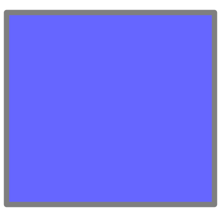
Categorical Association

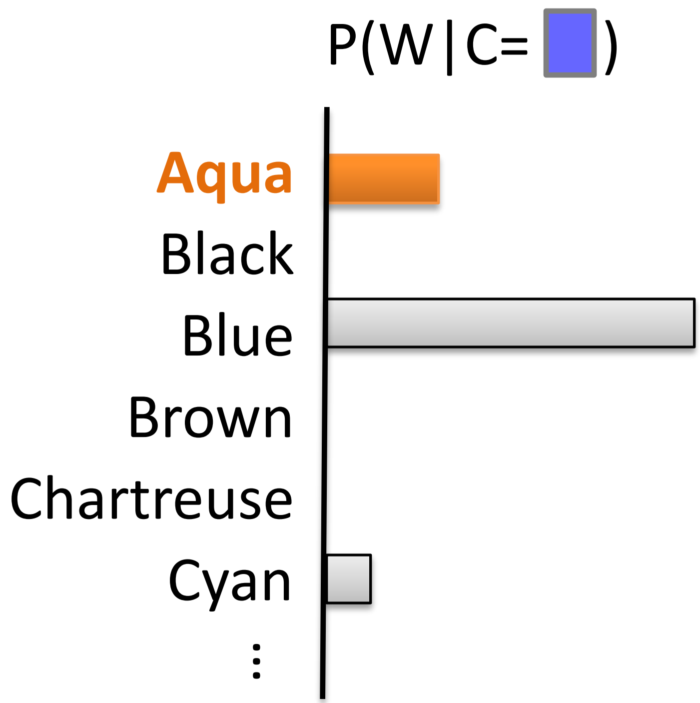
- Represent a color by other “example” colors

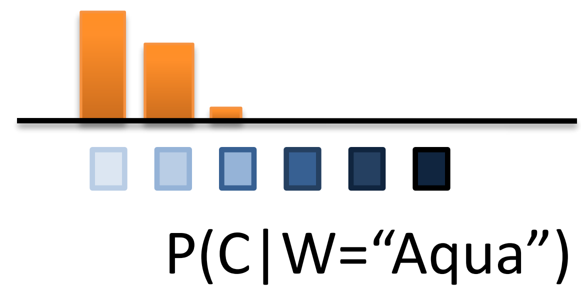


Categorical Association

- Represent a color by other “example” colors







Categorical Association

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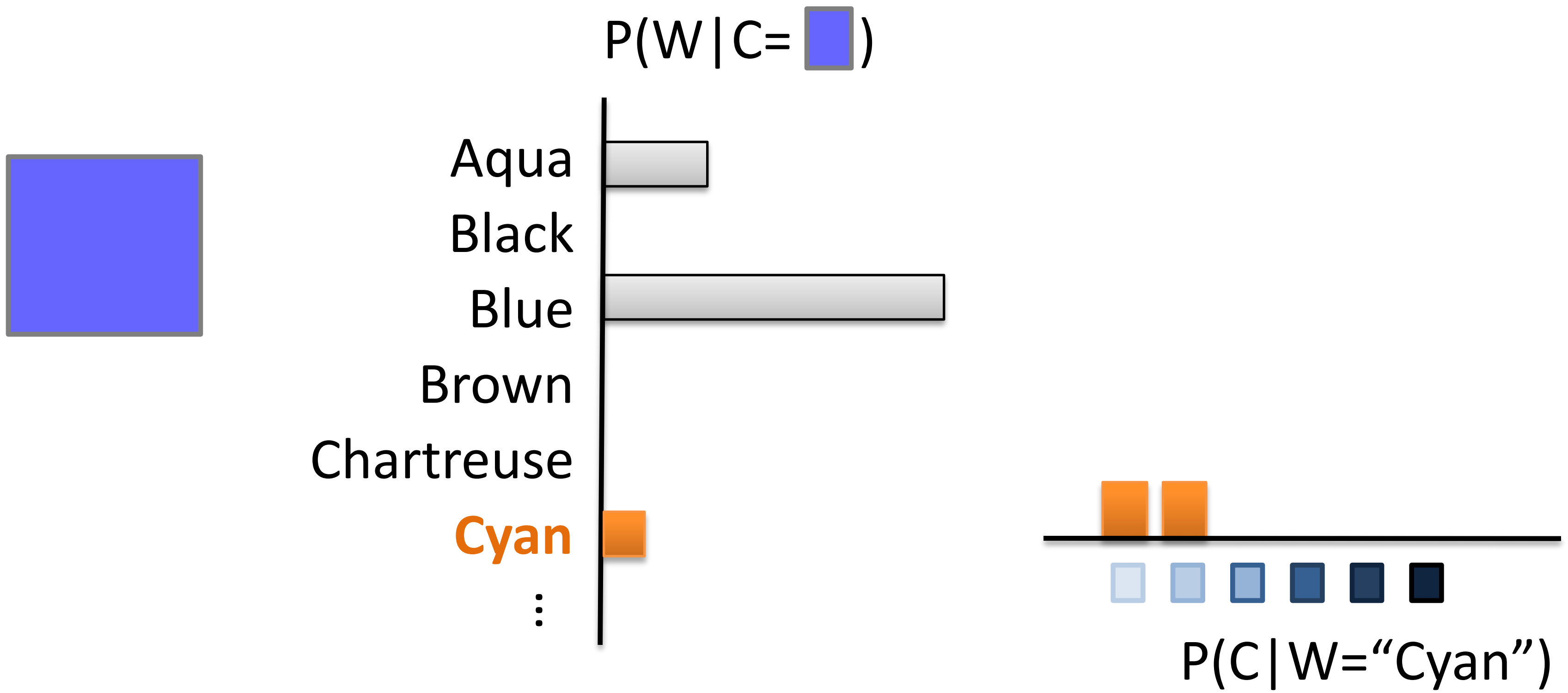
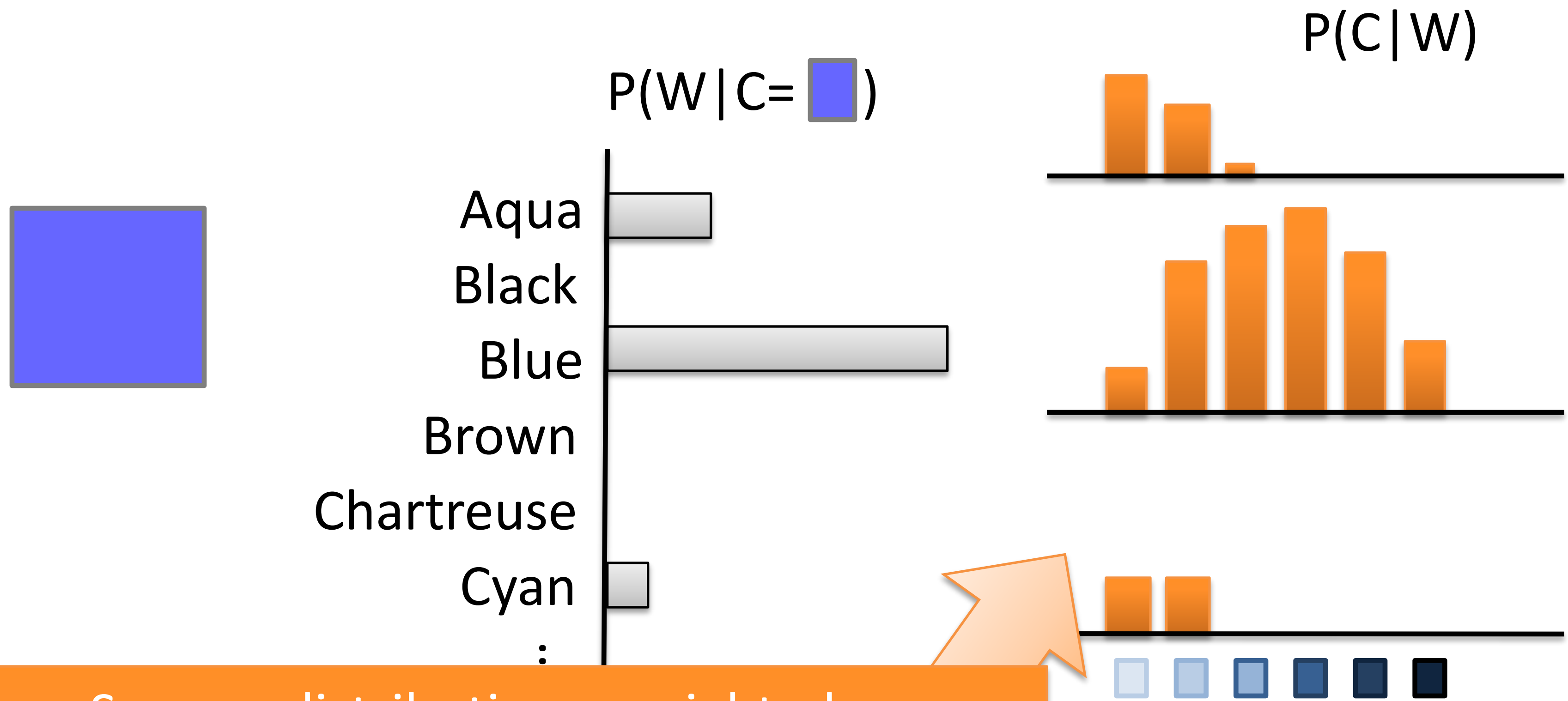


Categorical Association

- Represent a color by other "example" colors



Sum up distributions, weighted
by the frequency of the word.

Categorical Association

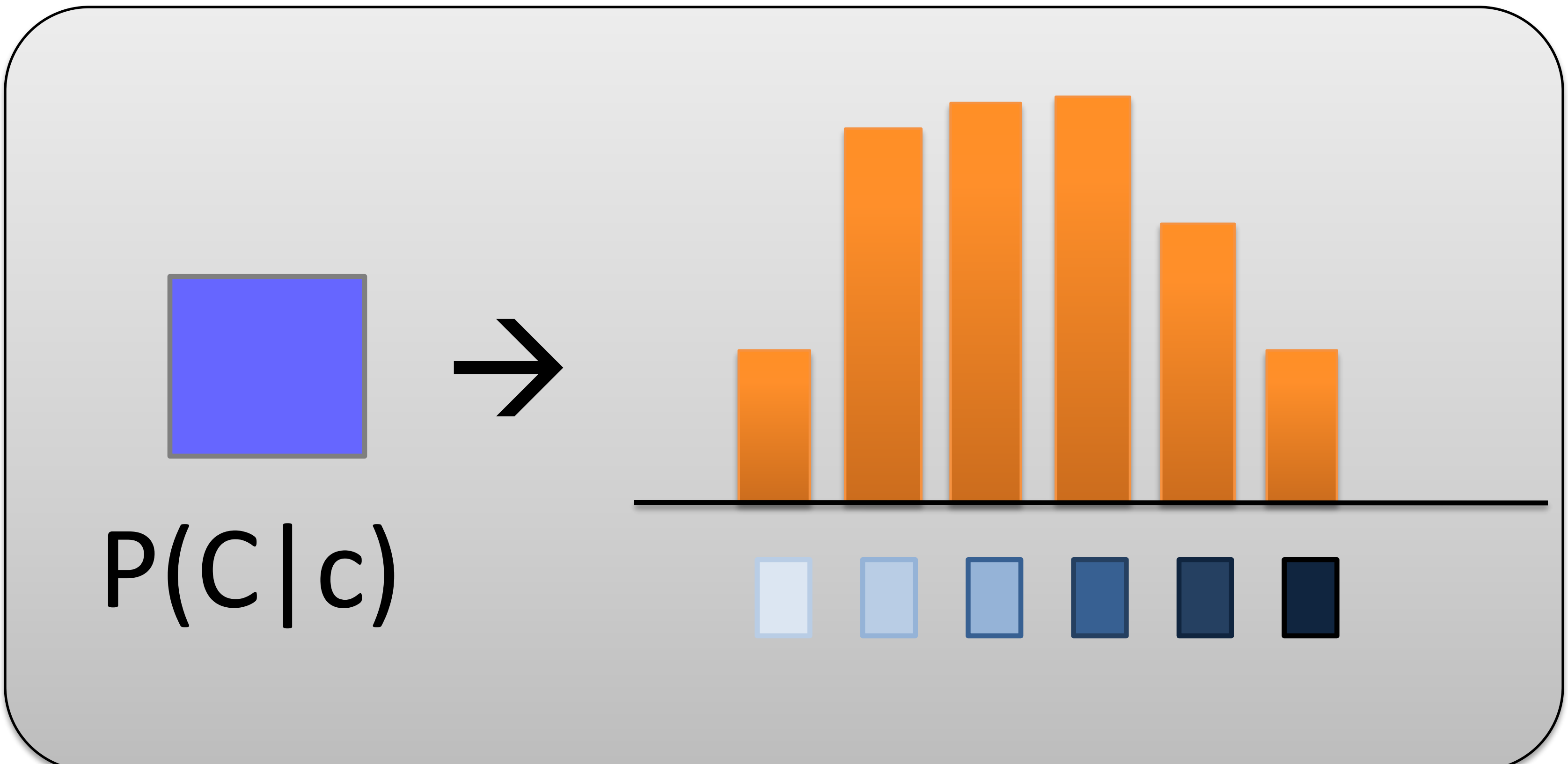
- Represent a color by other “example” colors

$$P(C|c=\blacksquare) = \sum_W P(C|w)P(w|c=\blacksquare)$$

- Sum contribution from all color words, weighted by frequency of word

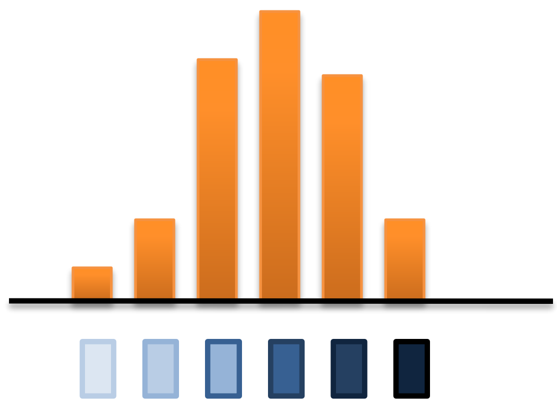
Categorical Association

- Represent a color by other “example” colors.



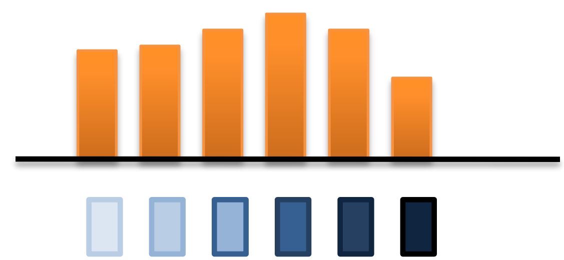
Color Saliency

- Entropy = “Uncertainty”



Low Entropy
Strongly associated
with a few colors

High Saliency

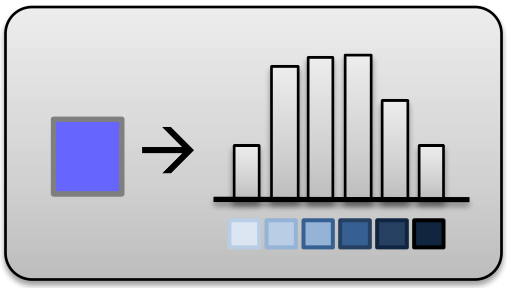


High Entropy
Weakly associated
with many colors

Low Saliency

- Saliency = $-\,H(C|c=\blacksquare) = -\,P(C|c)\log(\,P(C|c)\,)$

Categorical Association



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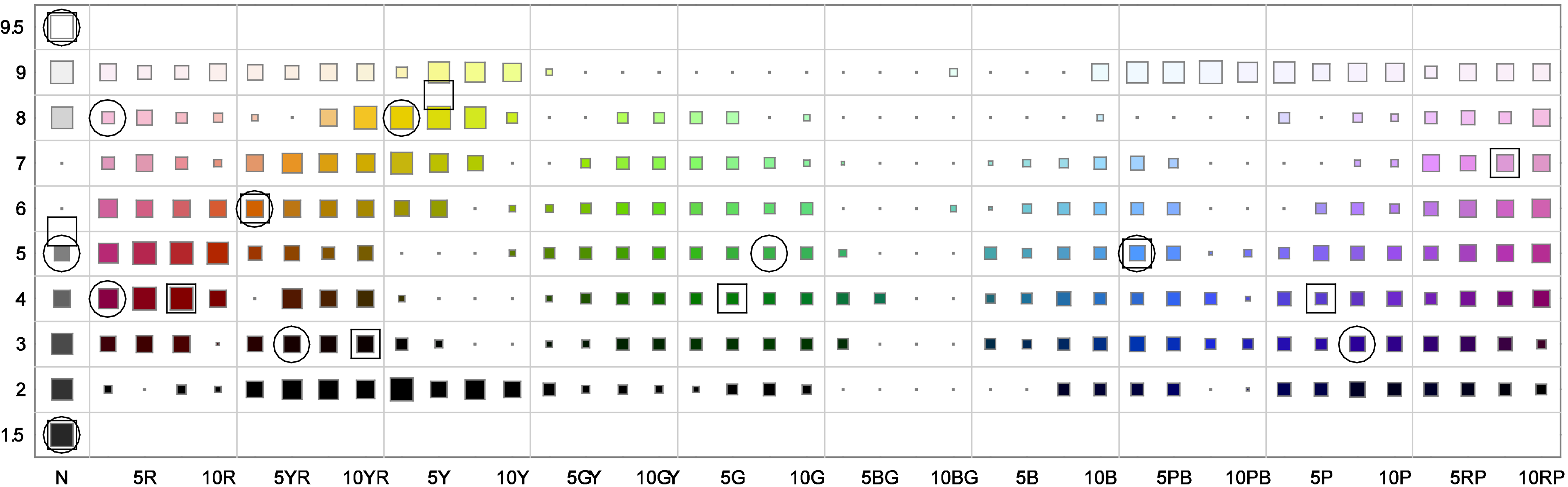
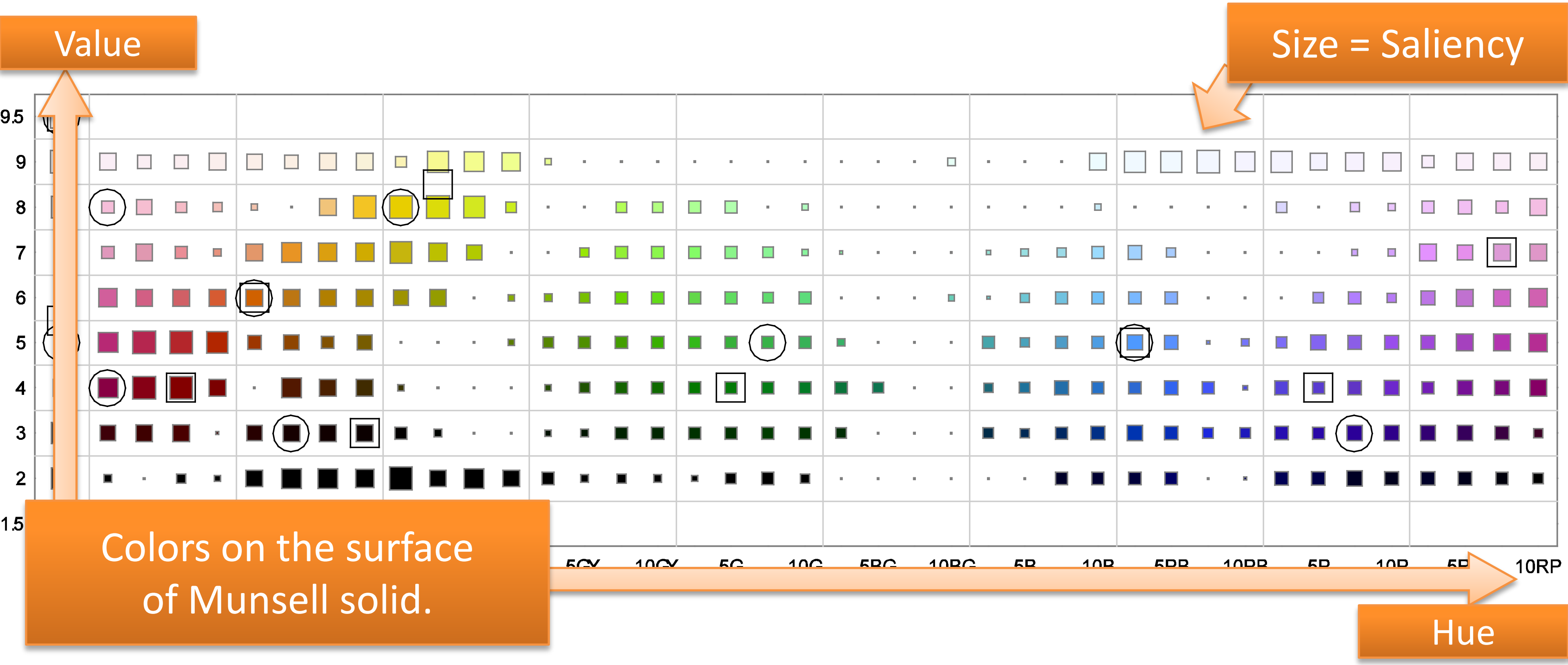
Color Saliency on Munsell Surface



- Based on 6 languages from World Color Survey
- How does saliency match known color foci?

Color Saliency on Munsell Surface



- Based on 6 languages from World Color Survey
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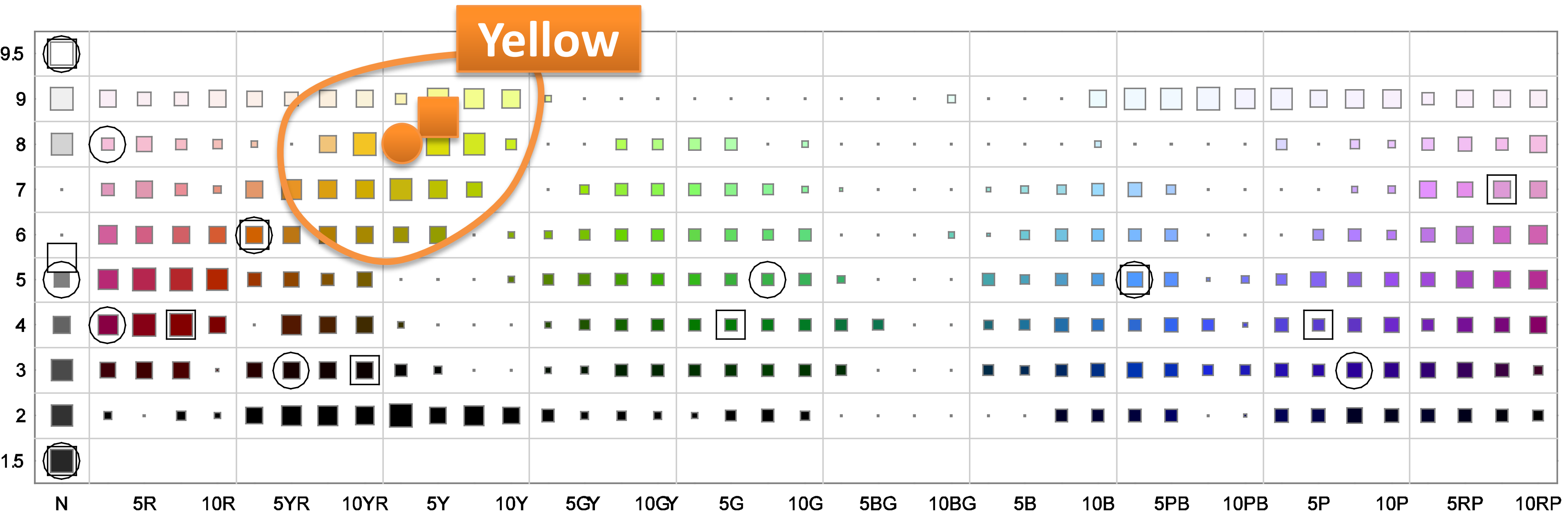
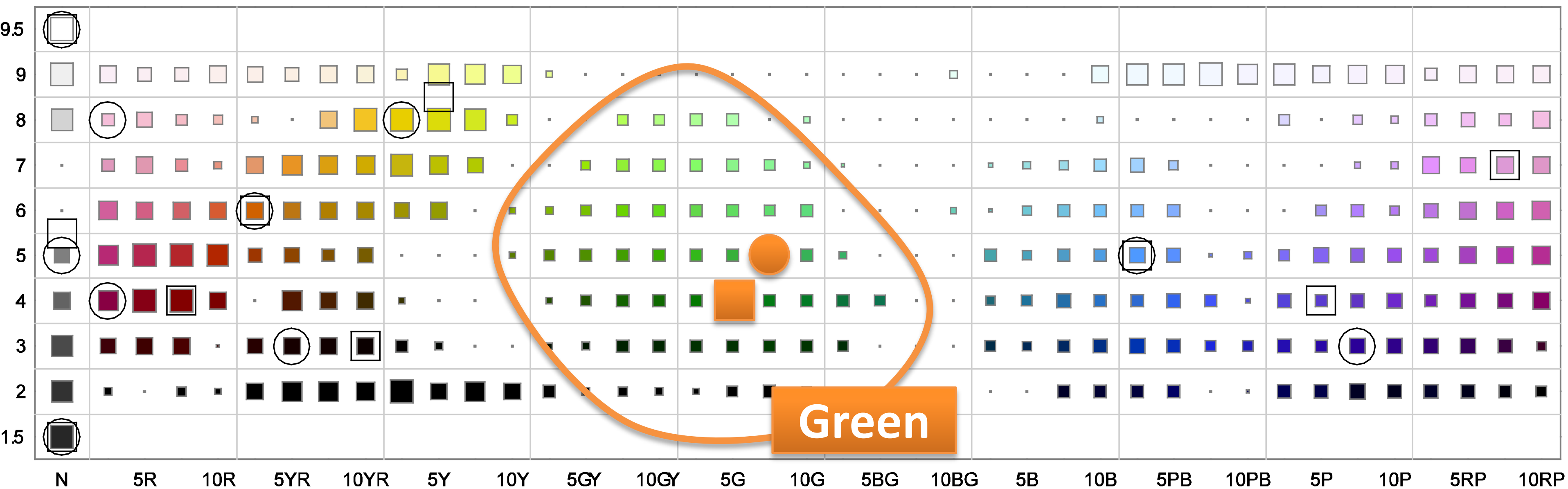
Correspondence with Known Foci



- English basic color foci observed by
  - = Berlin and Kay (1969)
  - = Sturges and Whitfield (1995)

Correspondence with Known Foci



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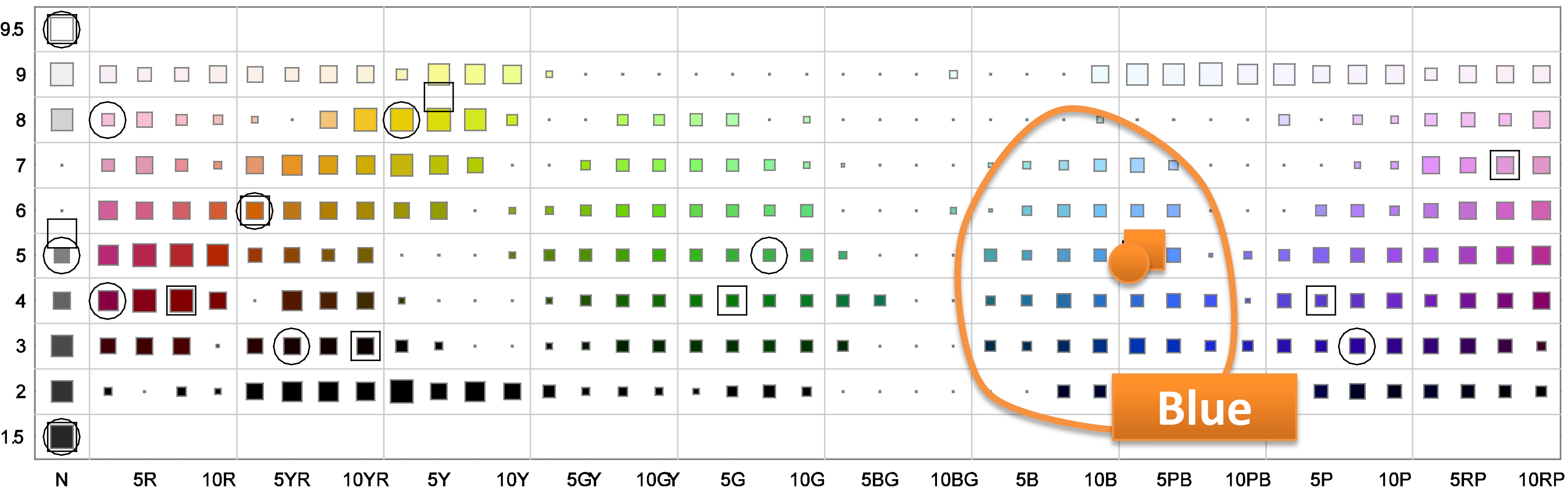

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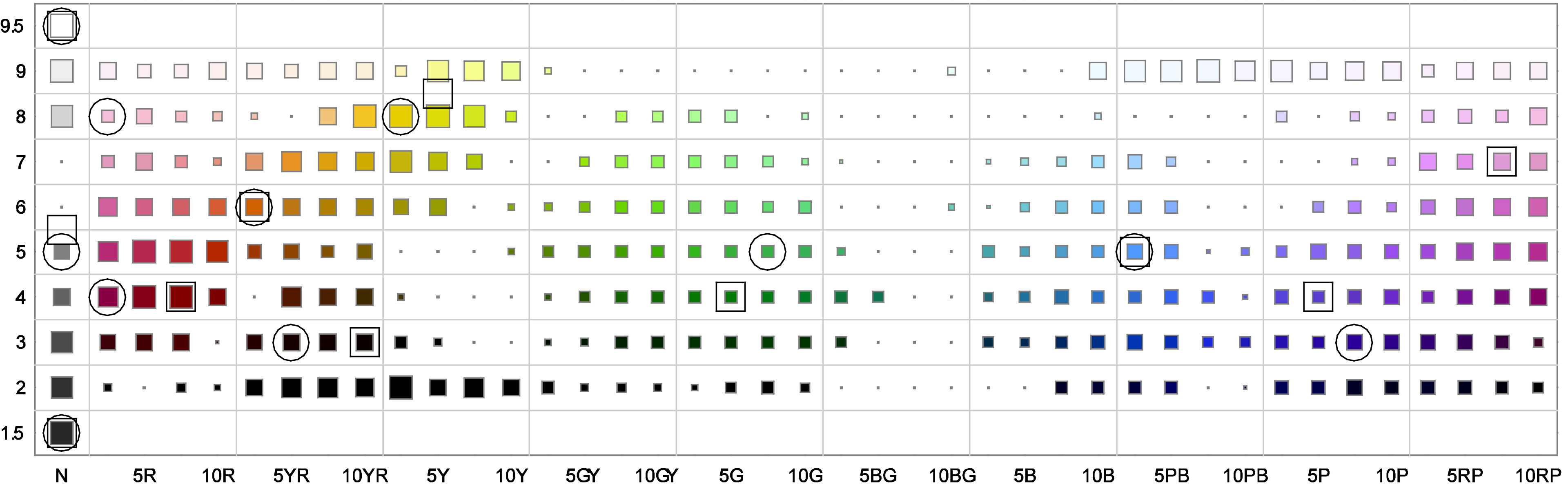

- English basic color foci observed by
  - ⬤ = Berlin and Kay (1969)
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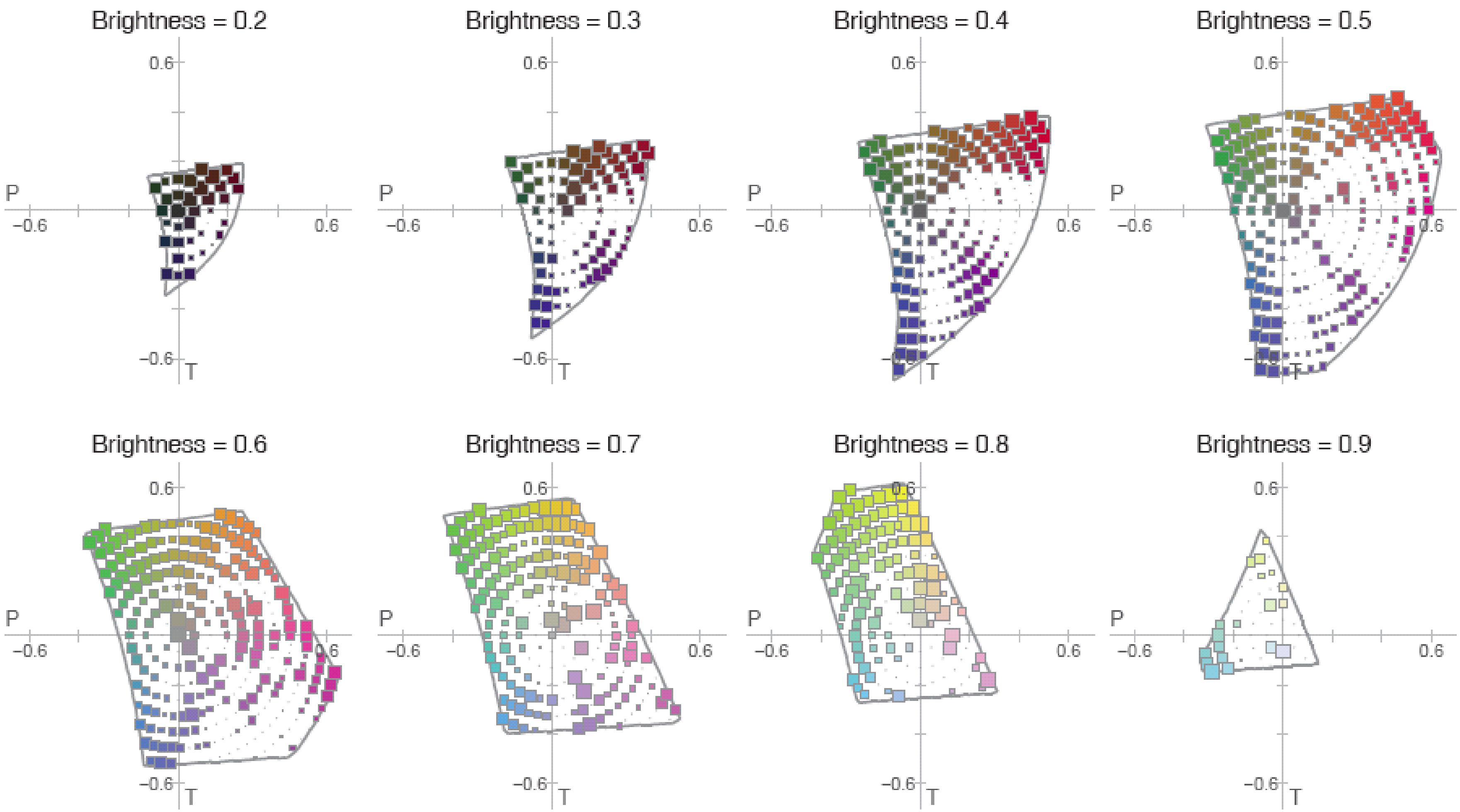
DoloresLabs Naming Data

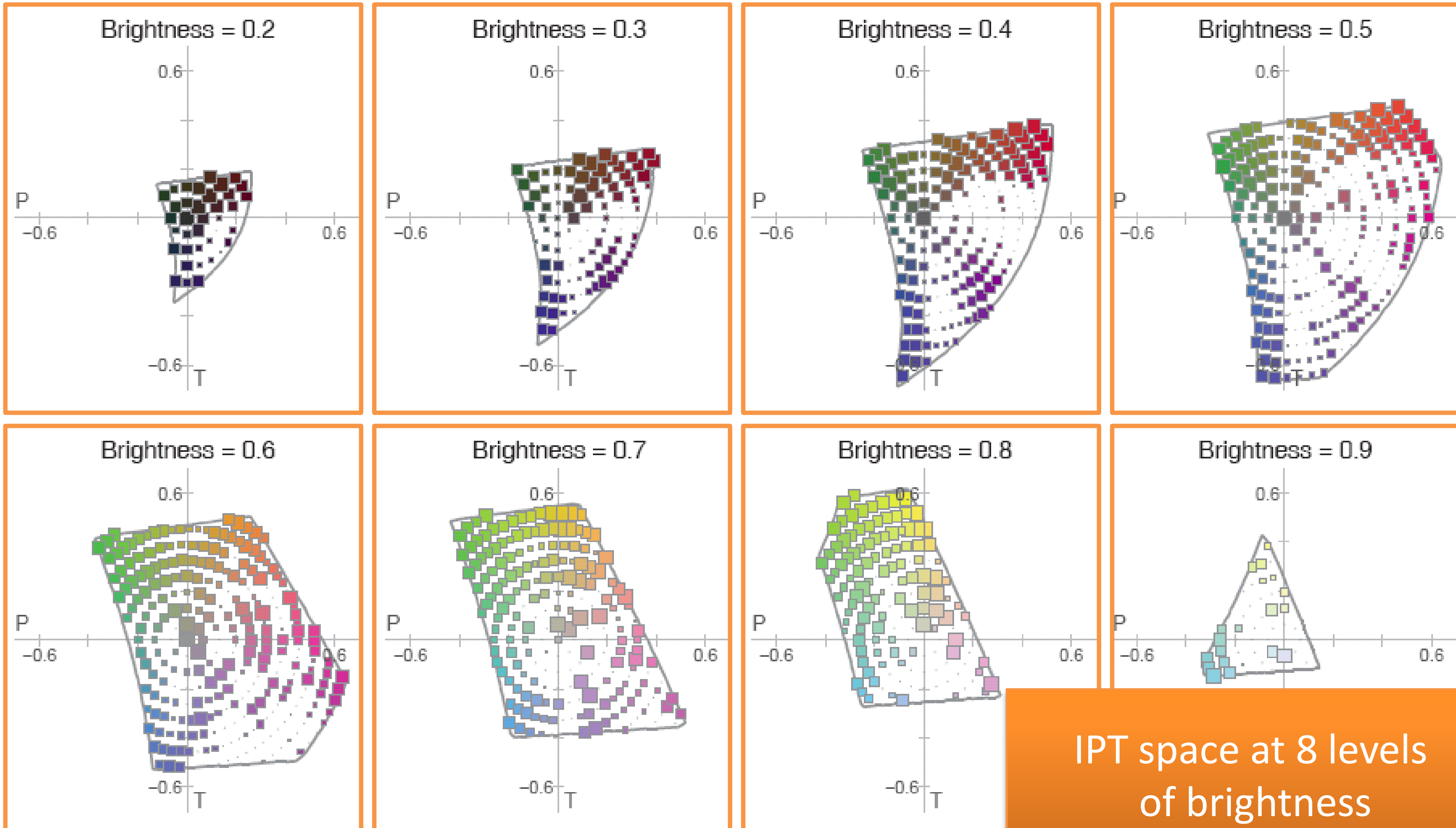
- Unconstrained online naming survey
  - 10,000 colors from 238 speakers
  - 1,966 distinct responses (raw ASCII strings)
  - 1,740 distinct phrases (spellings & punctuations)
  - 302 distinct words
- Non-uniformly sampled from RGB space

Color Saliency in sRGB Gamut



- Plotted in IPT space (assuming sRGB)

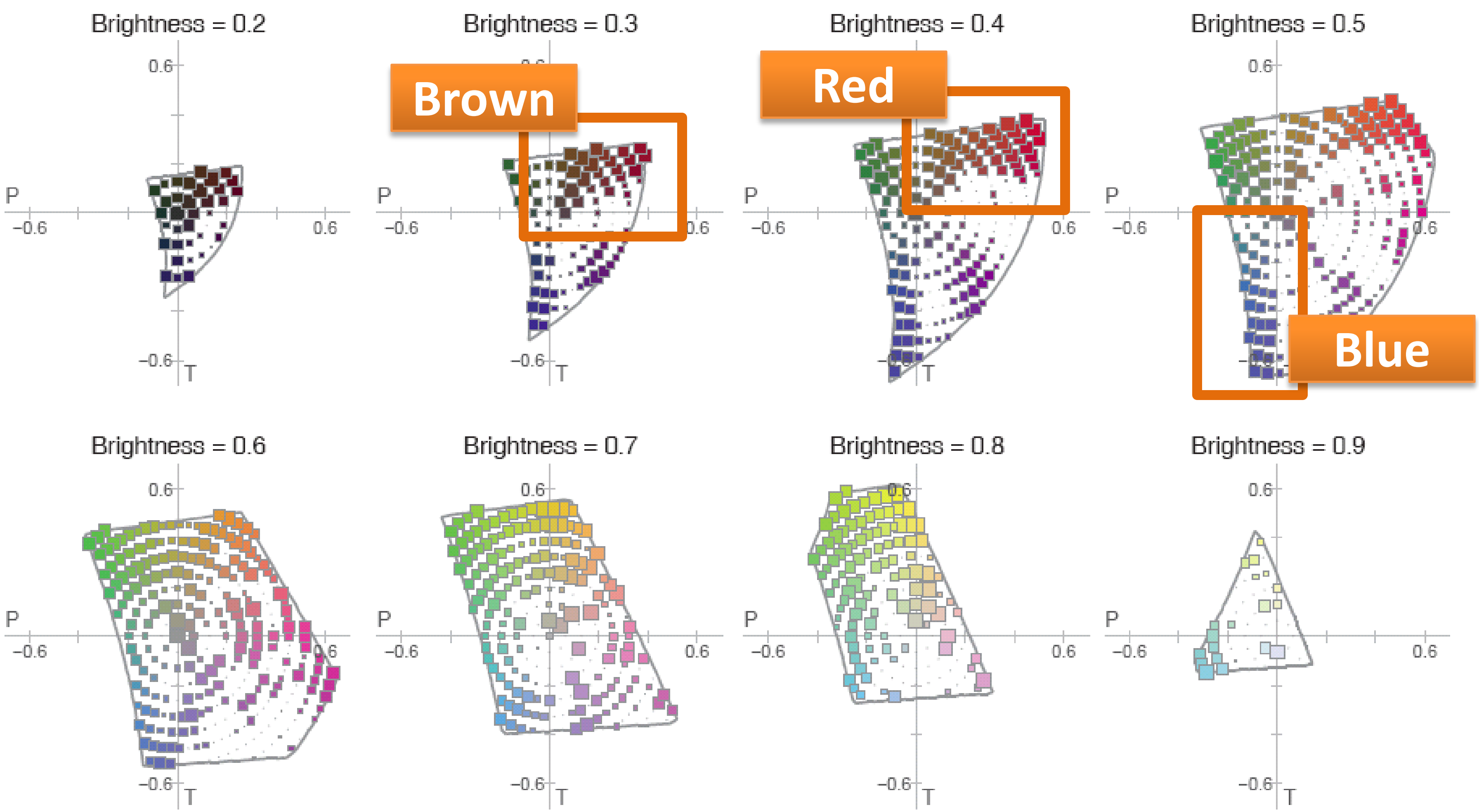
Color Saliency in sRGB Gamut



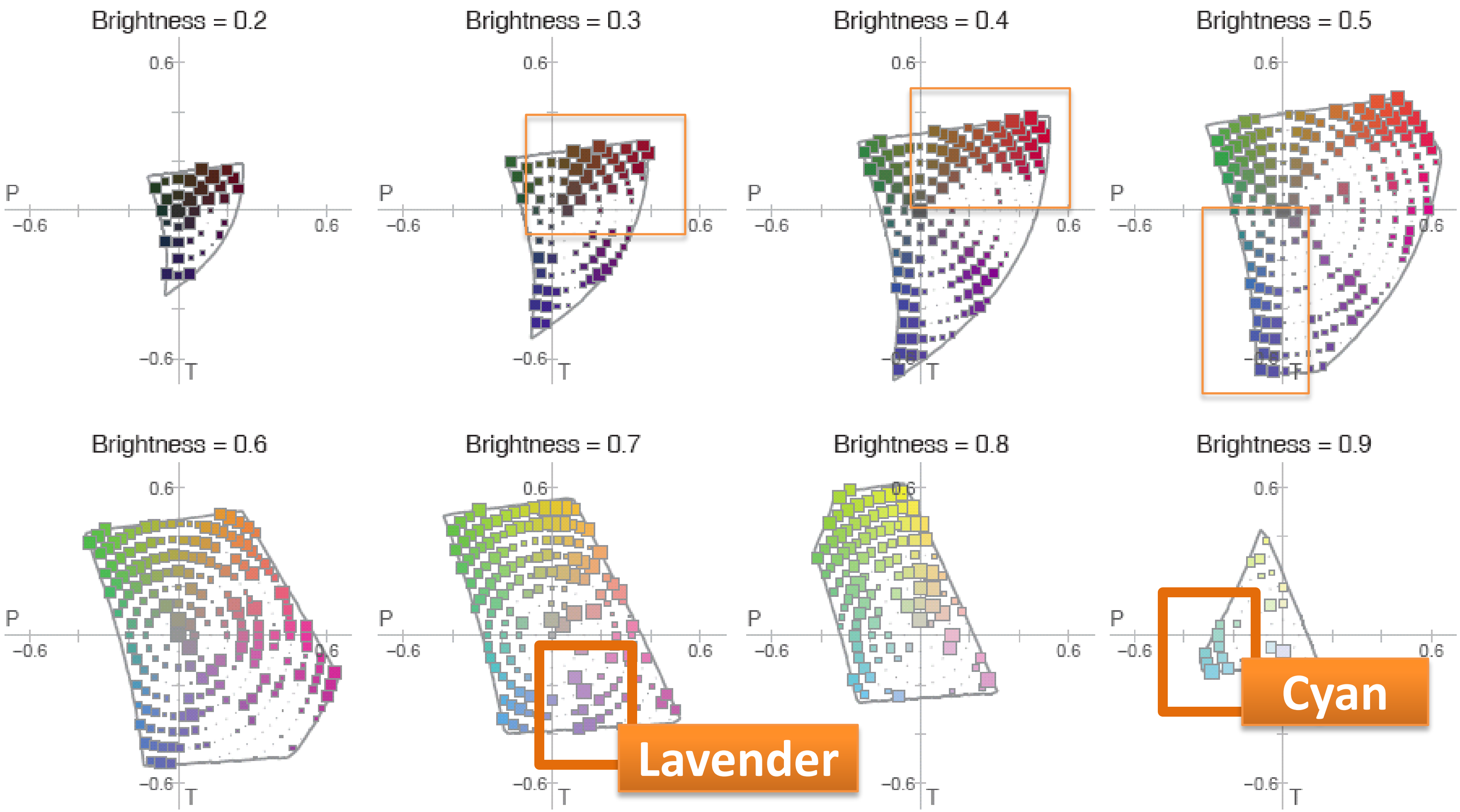
IPT space at 8 levels of brightness

- Plotted in IPT space (assuming sRGB)

Clusters of Salient Basic Colors



Clusters of Salient Non-Basic Colors



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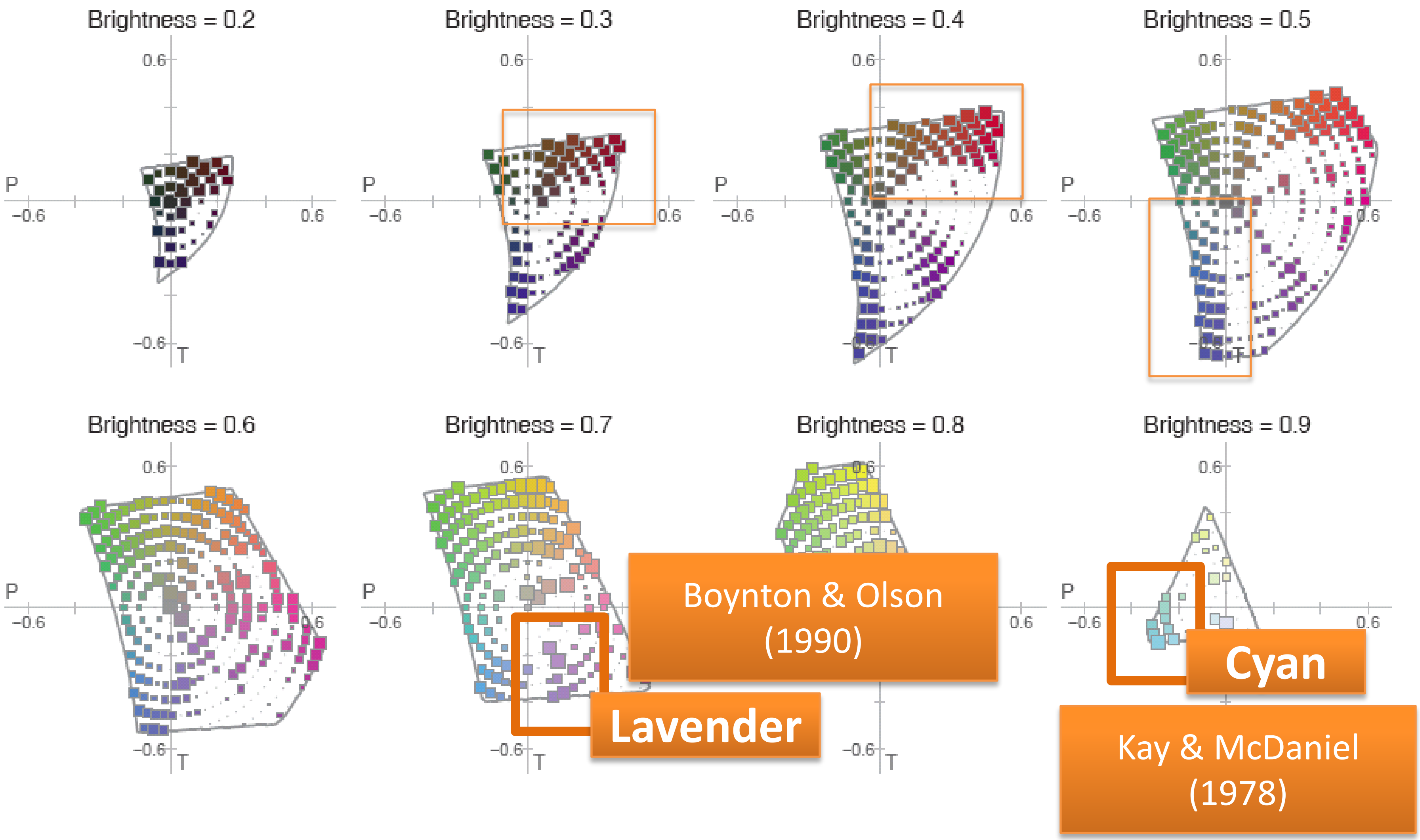
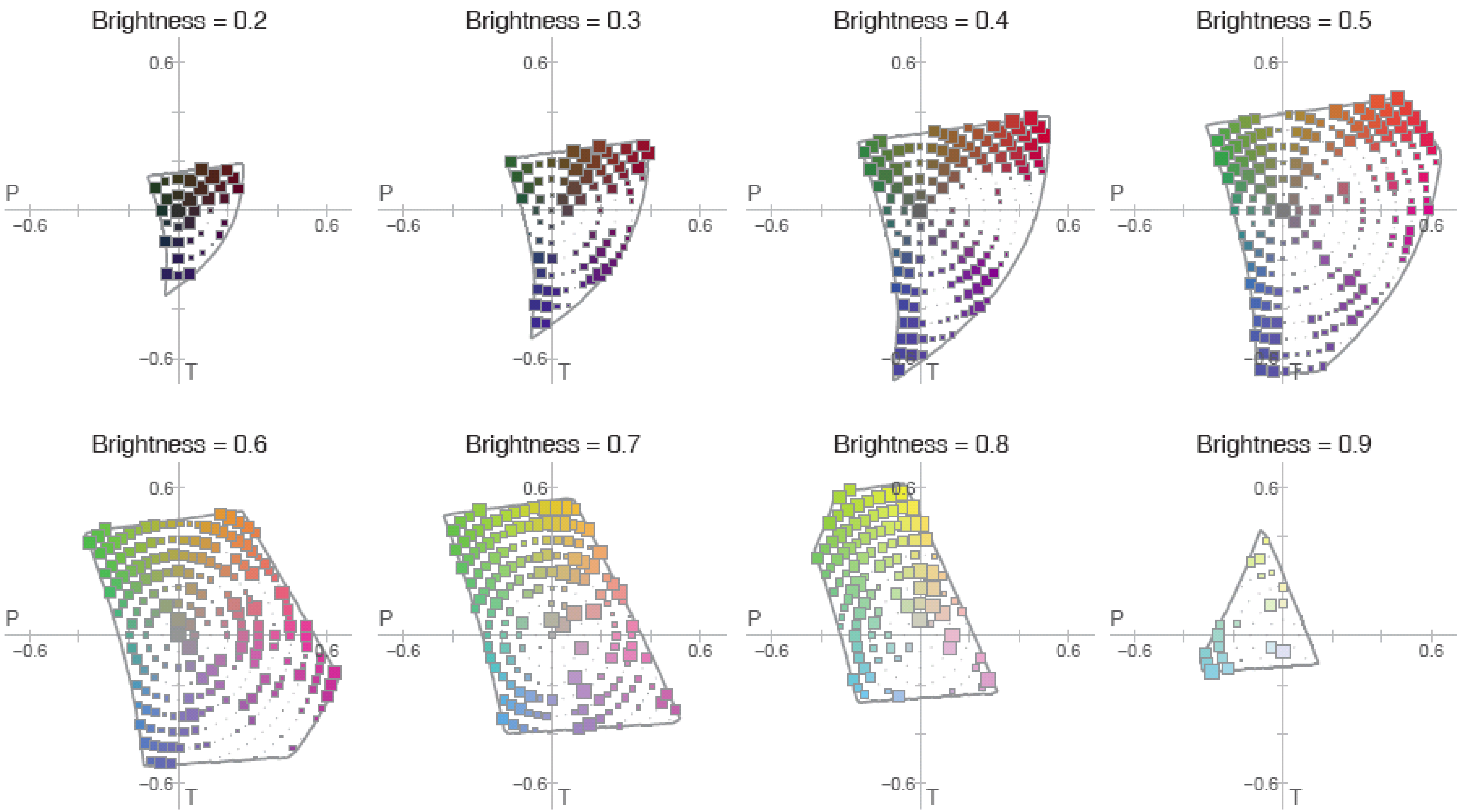
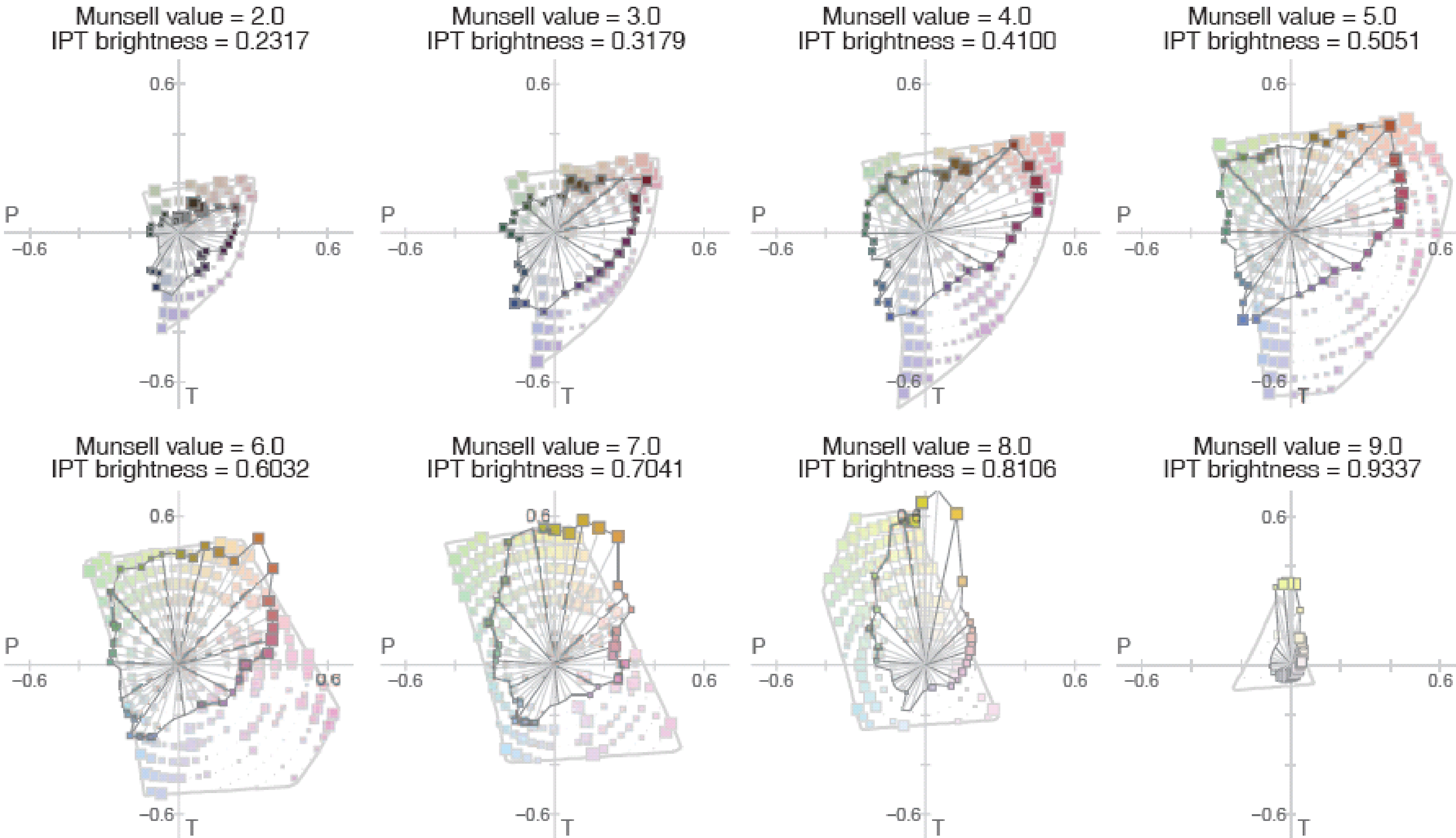


Color Saliency in sRGB Gamut



Comparison of Munsell/sRGB



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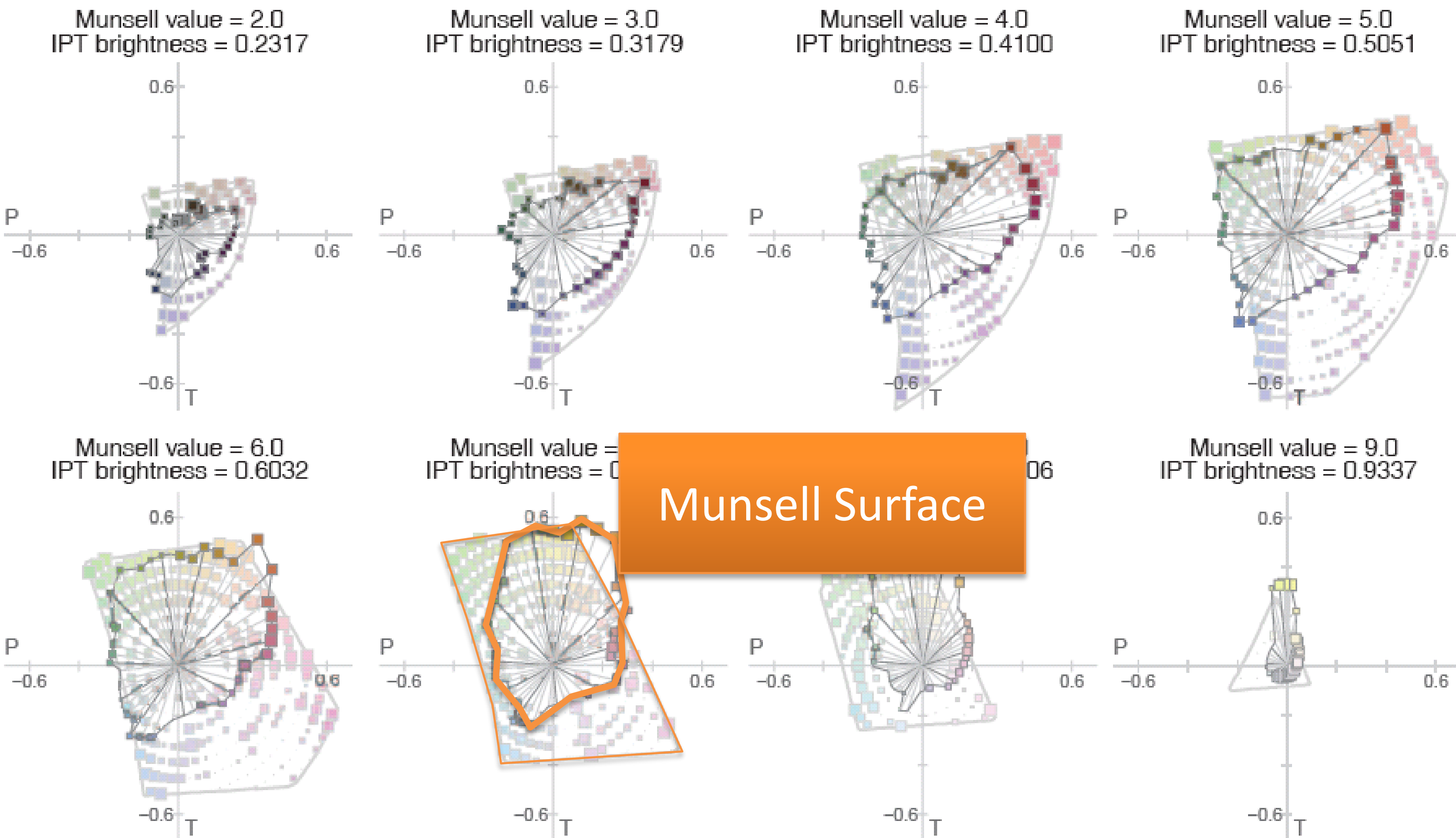

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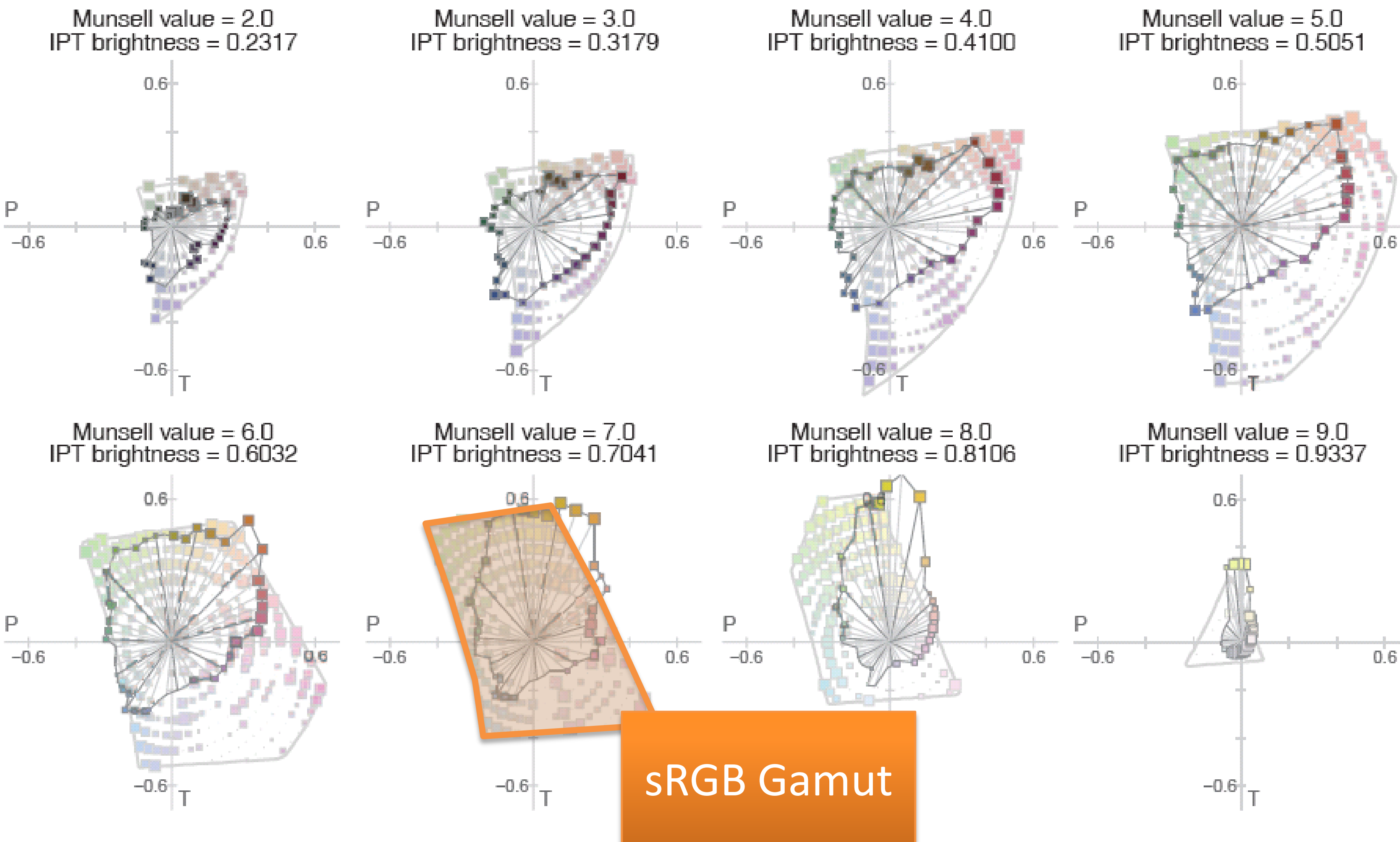

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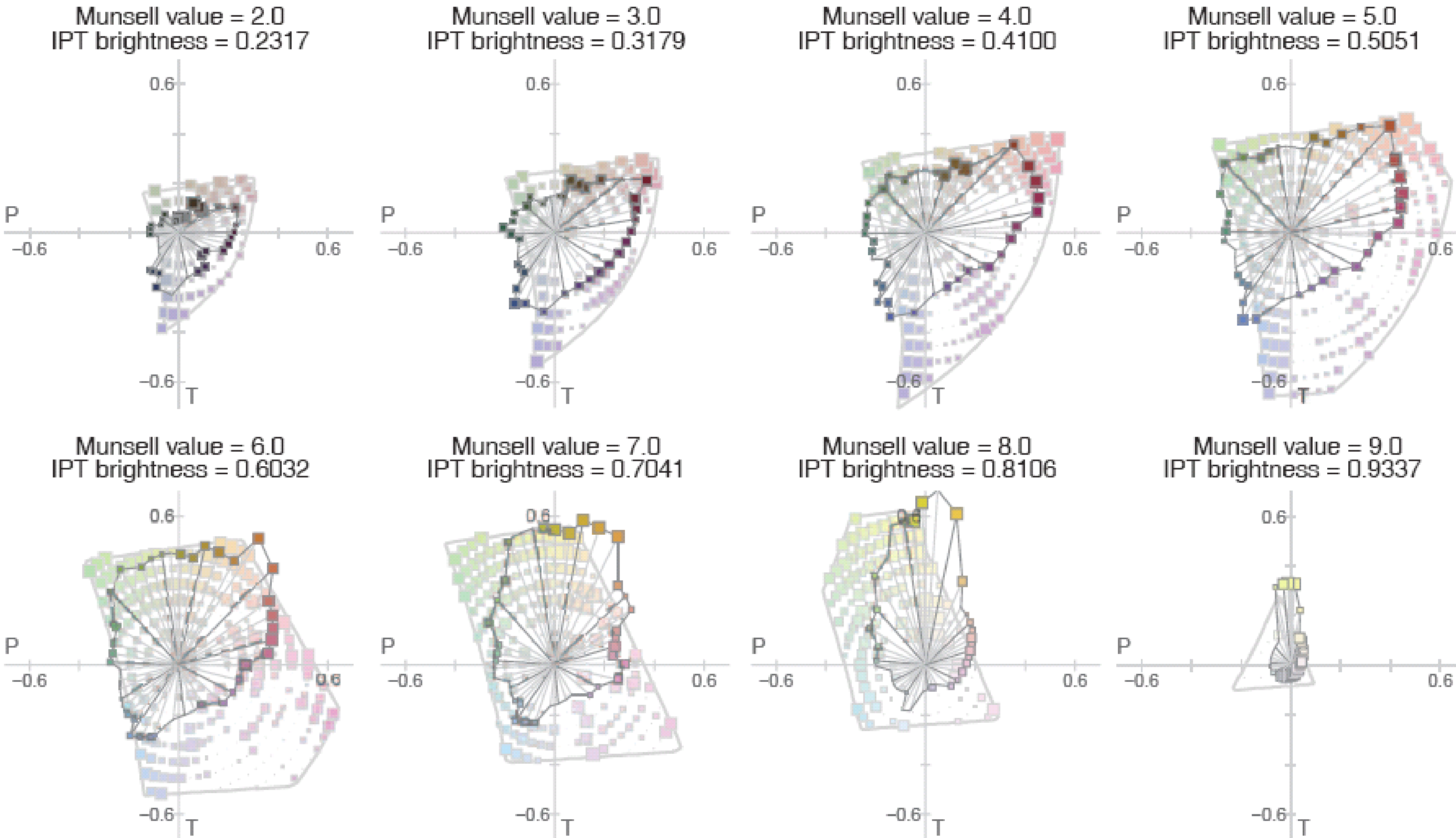
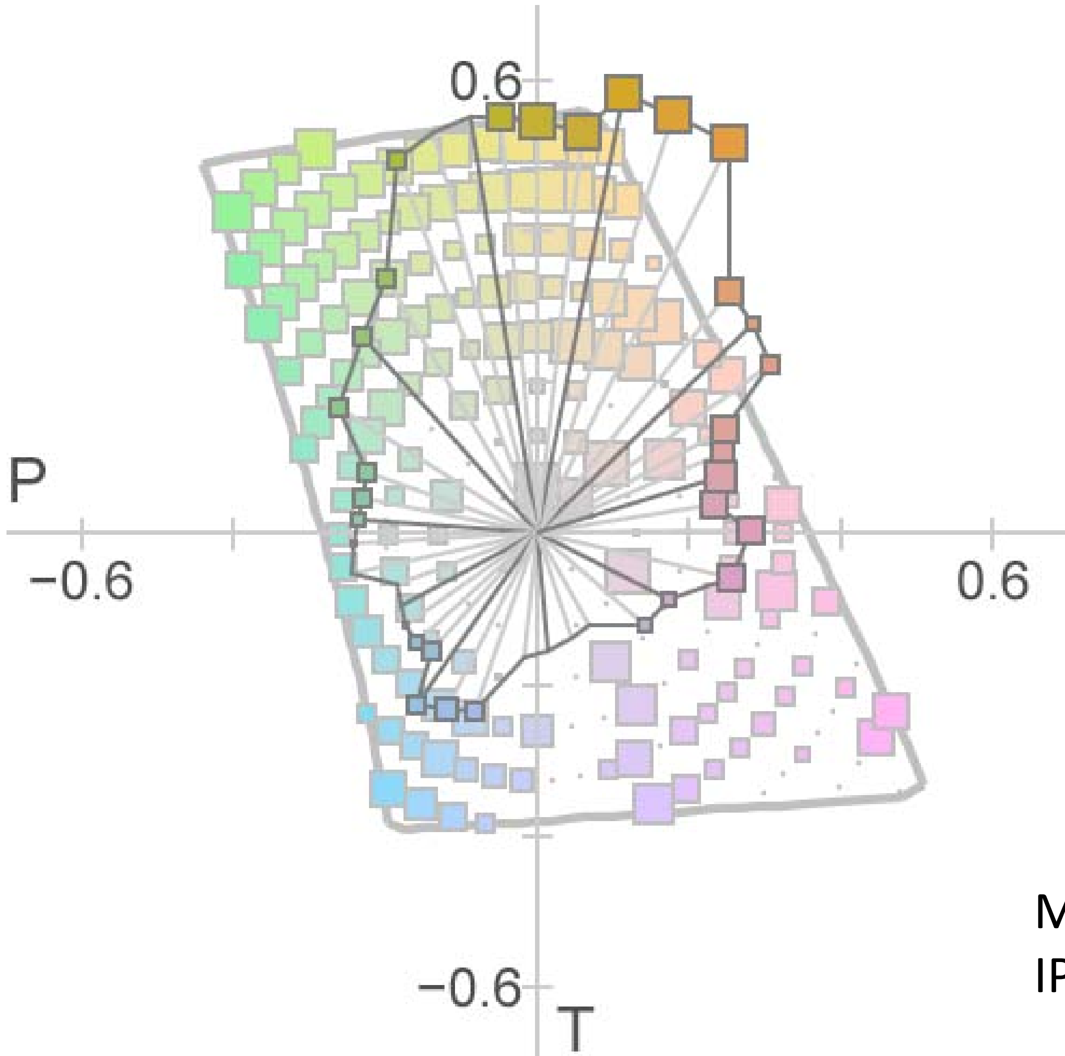
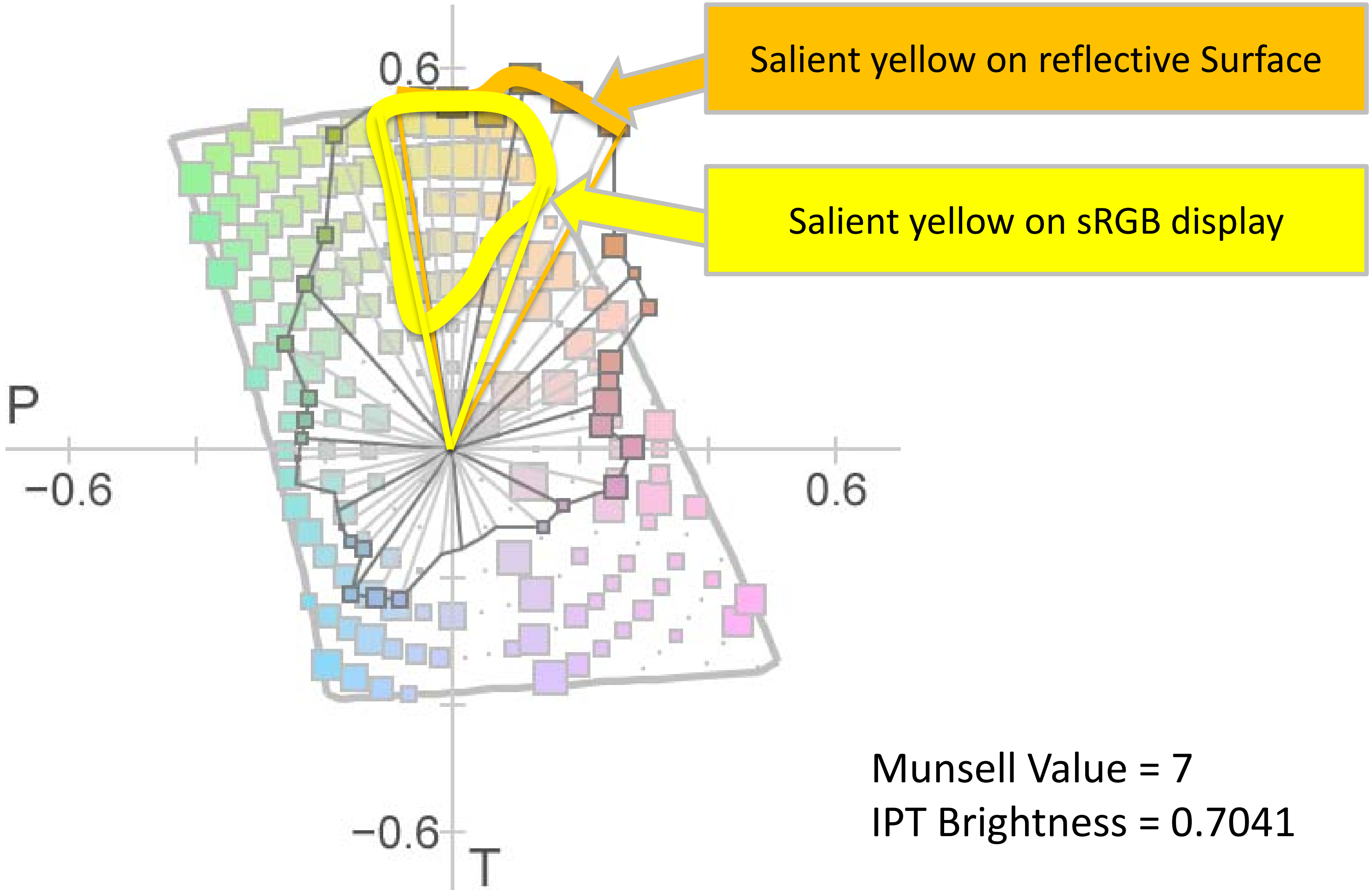


Comparison at Munsell Value=7



Munsell Value = 7
IPT Brightness = 0.7041

Comparison at Munsell Value=7



Munsell Value = 7
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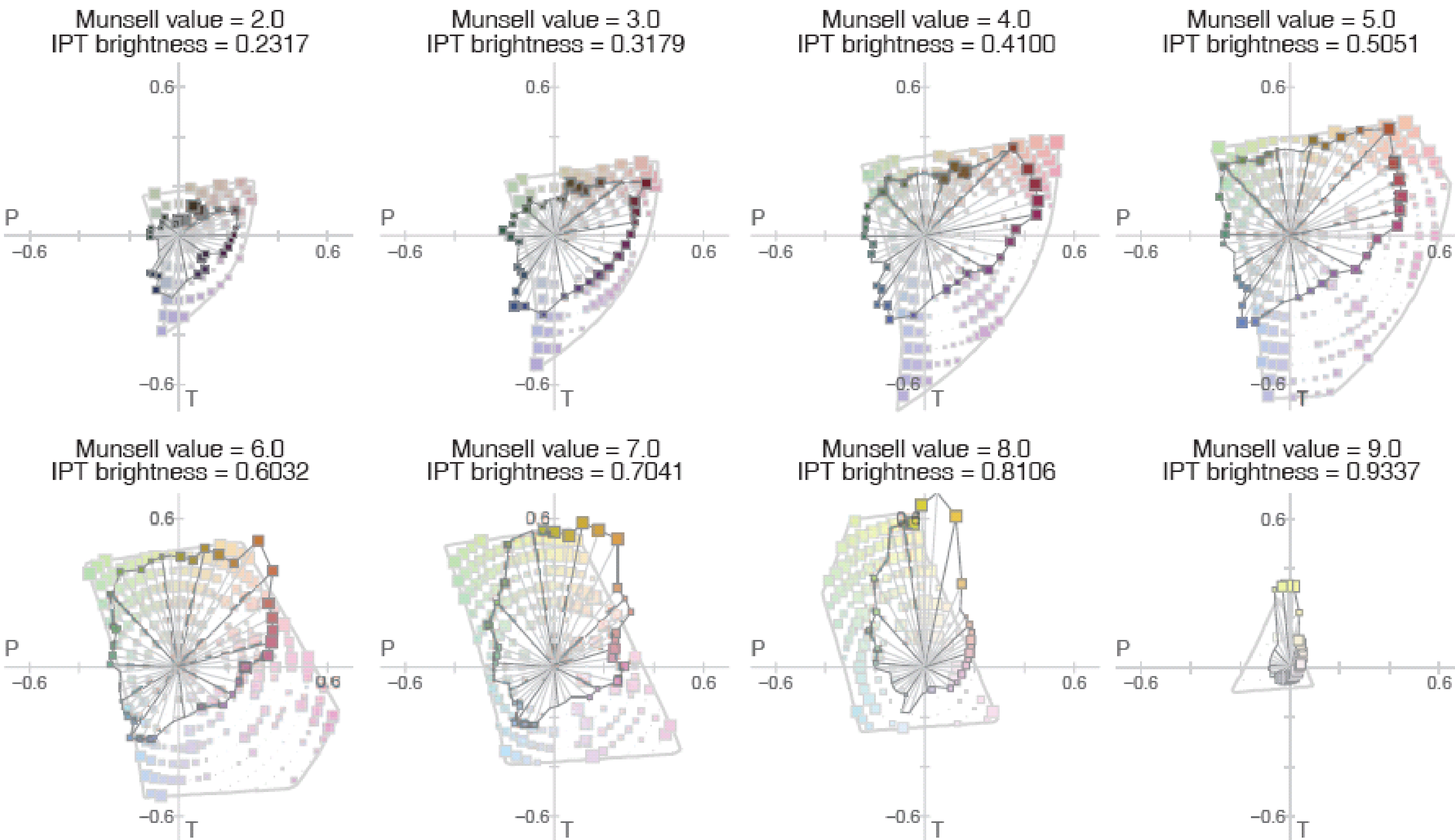
Saliency Differs for Munsell/sRGB



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Summary

- Categorical association between colors
  - Non-parametric model
    - Captured details and was robust on a large noisy dataset
  - Inclusion of all color words
    - Merged cross-linguistic data
    - Identified contributions from emerging non-basic terms
  - Computational tools
    - Saliency based on entropy
    - Saliency on Munsell surface and for sRGB Gamut