



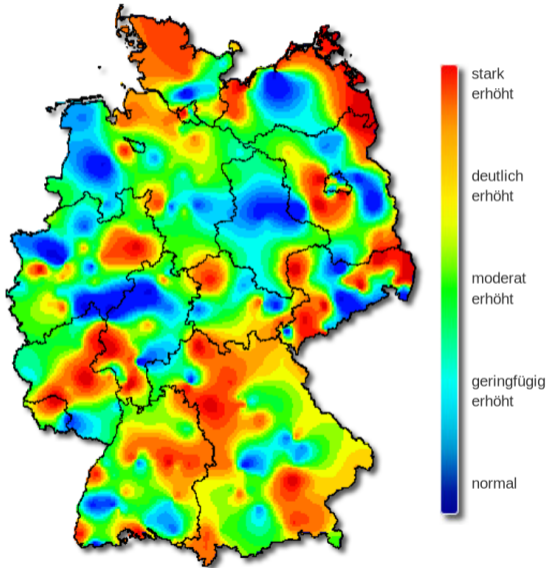
# colorspace

## A Toolbox for Manipulating and Assessing Color Palettes for Statistical Graphics

Achim Zeileis, Jason C. Fisher, Kurt Hornik, Ross Ihaka, Claire D. McWhite, Paul Murrell, Reto Stauffer, Claus O. Wilke

<http://colorspace.R-Forge.R-project.org/>

# Motivation

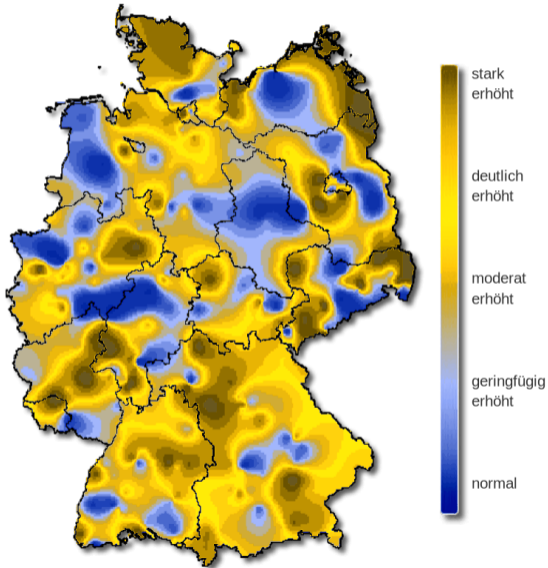


**Map:** Influenza severity in Germany (week 8, 2019).

**Source:** Arbeitsgemeinschaft Influenza, Robert-Koch-Institut.

**Reported in:** SPIEGEL Online, Tagesschau, ...

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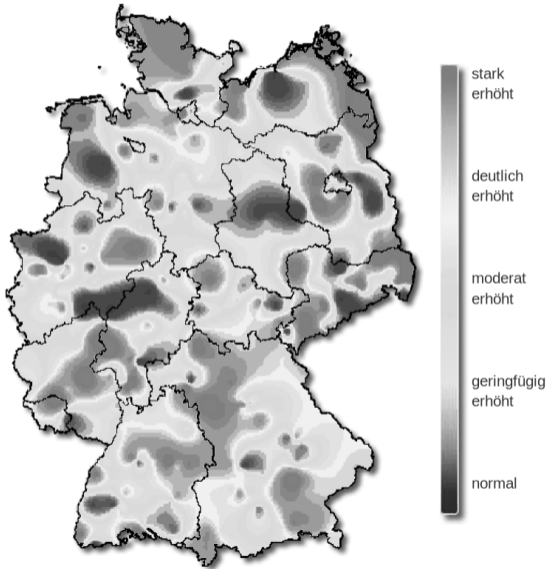
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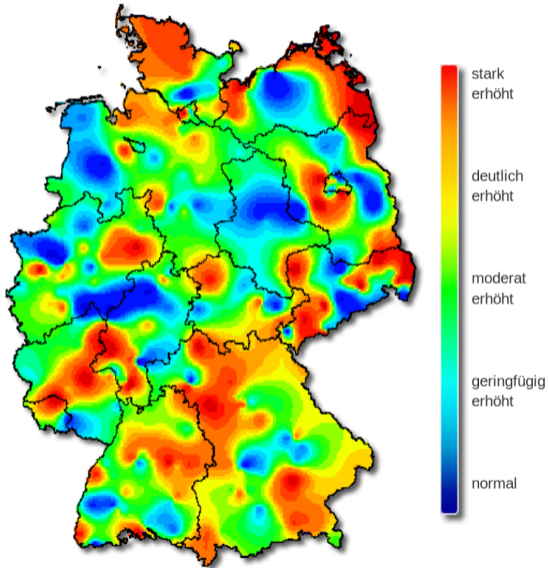
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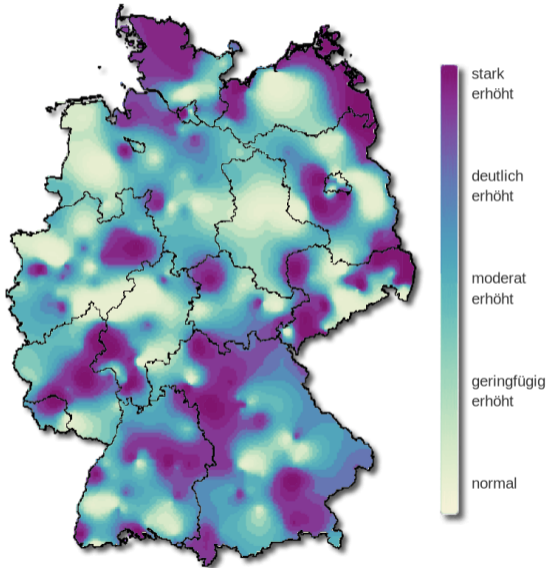
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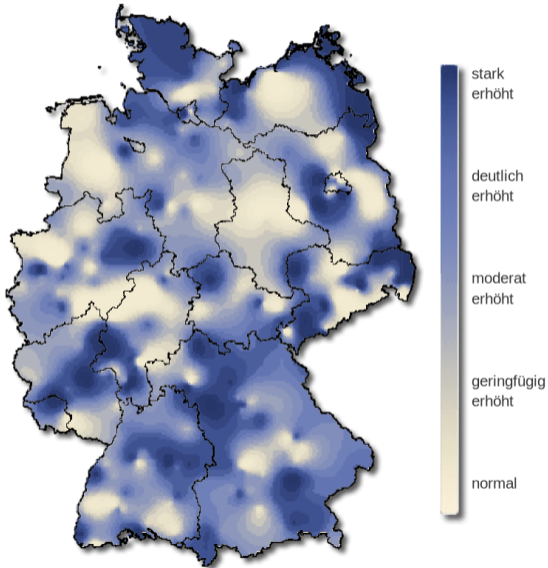
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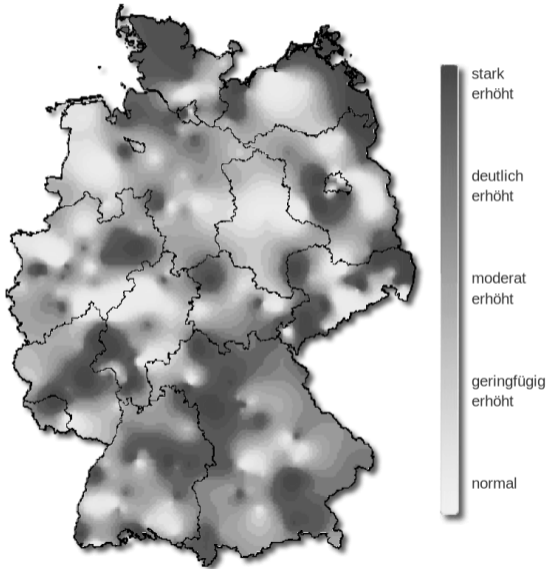
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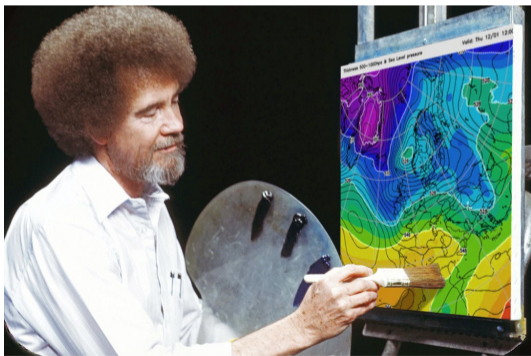
## **Need tools for:**

- Construction of palettes with better perceptual properties.
- Assessment of color palettes.
- Manipulation of colors.

# Motivation

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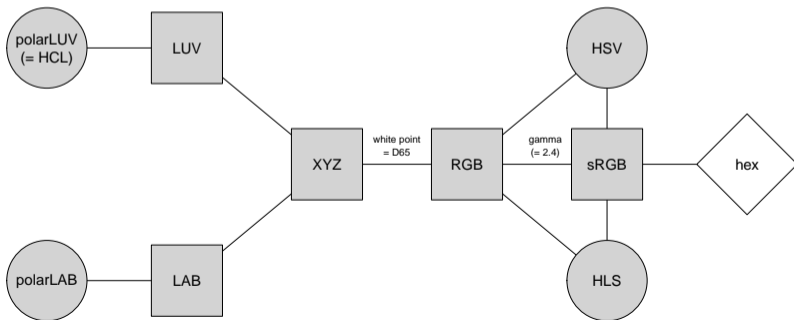


Because Bob Ross would not approve of this!

# Color spaces

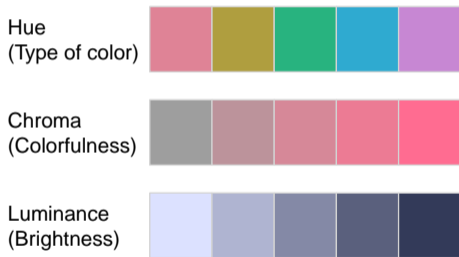
**Origin of the package:** Convert colors between various three-dimensional representations of color.

**In particular:** From the perceptually-based HCL (Hue-Chroma-Luminance) to standard Red-Green-Blue (sRGB, and corresponding hex codes) space.



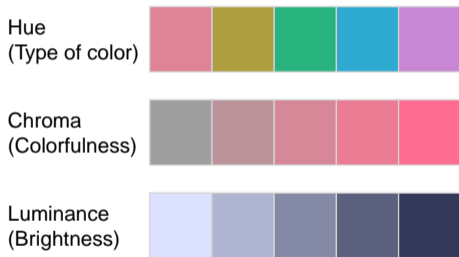
# HCL vs. RGB

**HCL:** Polar coordinates in CIELUV.  
Captures perceptual dimensions of  
the human visual system very well.

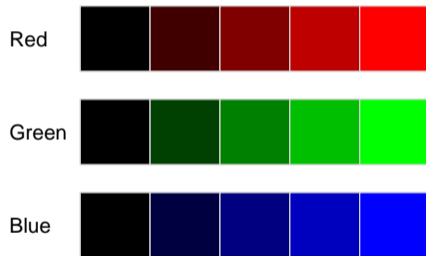


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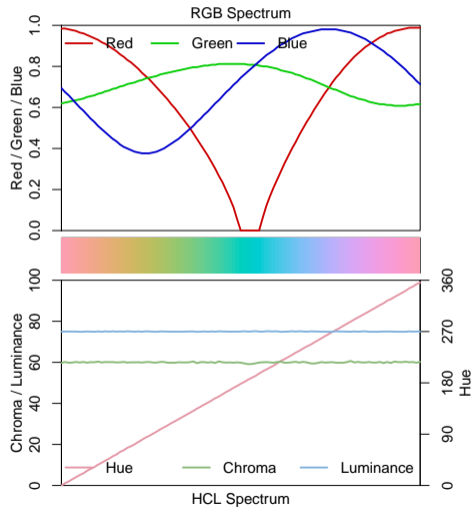
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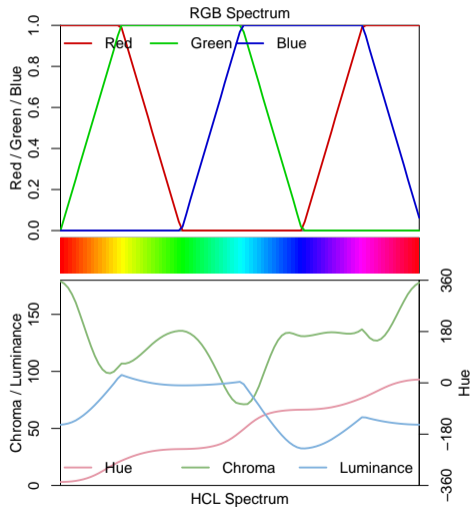
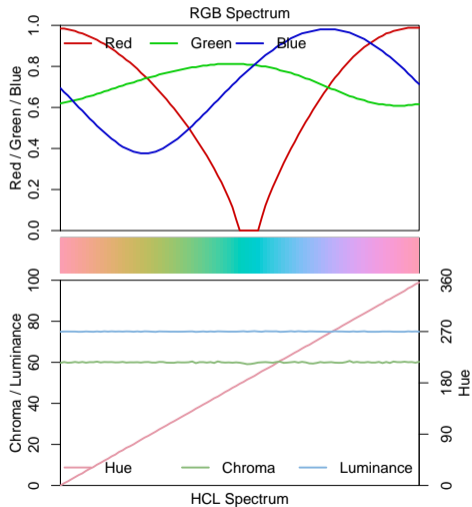
**RGB:** Motivated by how computers/TVs used to generate and still represent color.



# HCL vs. RGB: The End of the Rainbow



# HCL vs. RGB: The End of the Rainbow



# Color palettes: Somewhere over the Rainbow

## Qualitative (Set 2)



## Sequential (Blues 3)



## Diverging (Green–Brown)





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**Qualitative:** For categorical information, i.e., where no particular ordering of categories is available. Function: `qualitative_hcl()`.

# Color palettes: Somewhere over the Rainbow

## Qualitative (Set 2)



## Sequential (Blues 3)



## Diverging (Green–Brown)



**Qualitative:** For categorical information, i.e., where no particular ordering of categories is available. Function: `qualitative_hcl()`.

**Sequential:** For ordered/numeric information, i.e., where colors go from high to low (or vice versa). Function: `sequential_hcl()`.

# Color palettes: Somewhere over the Rainbow

## Qualitative (Set 2)



## Sequential (Blues 3)



## Diverging (Green–Brown)



**Qualitative:** For categorical information, i.e., where no particular ordering of categories is available. Function: `qualitative_hcl()`.

**Sequential:** For ordered/numeric information, i.e., where colors go from high to low (or vice versa). Function: `sequential_hcl()`.

**Diverging:** For ordered/numeric information around a central neutral value, i.e., where colors diverge from neutral to two extremes. Function: `diverging_hcl()`.

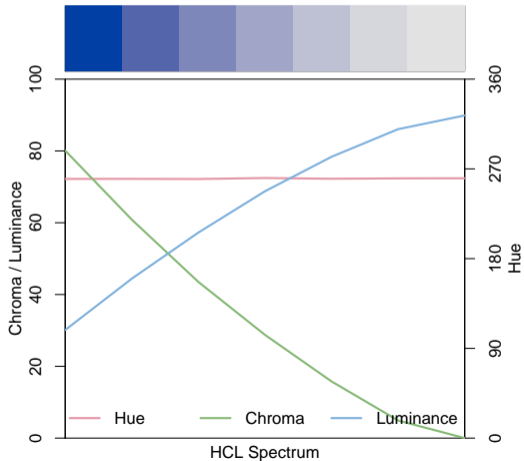
# Color palettes: Somewhere over the Rainbow

**Sequential:** Luminance contrast is crucial (dark to light or vice versa).



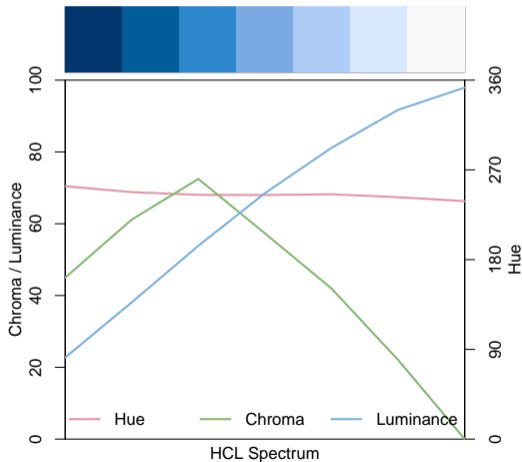
# Color palettes: Somewhere over the Rainbow

**Blues 2:** Single hue. Decreasing chroma with increasing luminance.



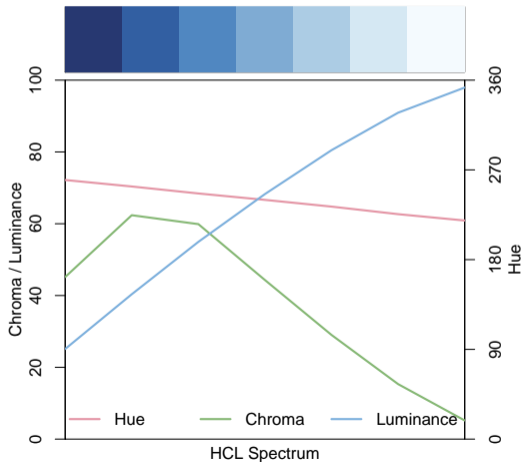
# Color palettes: Somewhere over the Rainbow

**Blues 3:** Single hue. Triangular chroma to achieve higher luminance contrast.



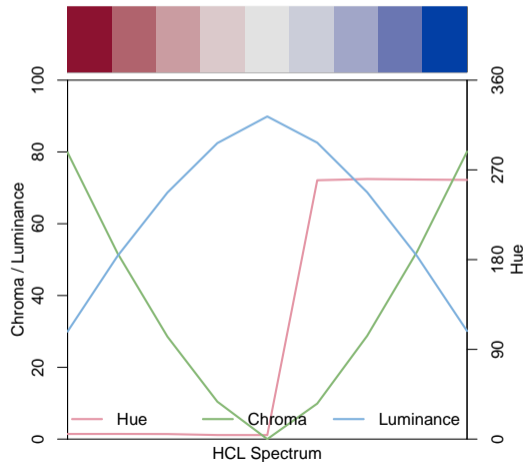
# Color palettes: Somewhere over the Rainbow

**Blues:** Multi hue. Triangular chroma. High luminance contrast.



# Color palettes: Somewhere over the Rainbow

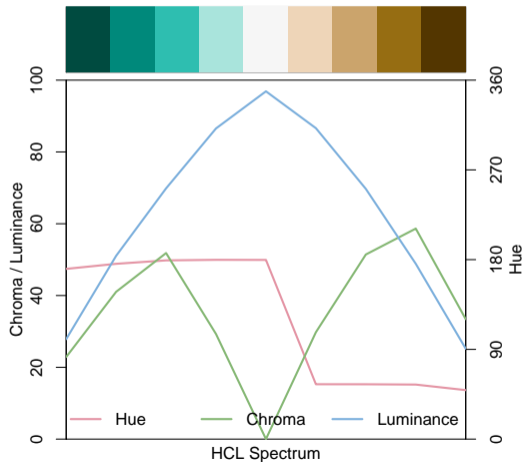
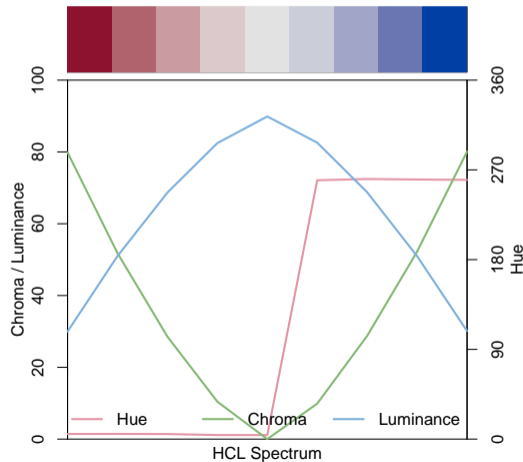
**Diverging:** Combine two sequential palettes with balanced chroma/luminance.





# Color palettes: Somewhere over the Rainbow

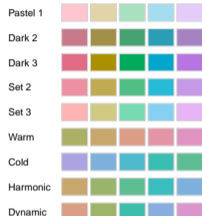
**Diverging:** Combine two sequential palettes with balanced chroma/luminance.



# Color palettes: Somewhere over the Rainbow

```
R> hcl_palettes(plot = TRUE)
```

## Qualitative



## Sequential (single-hue)



## Sequential (multi-hue)



# Statistical graphics

## Base:

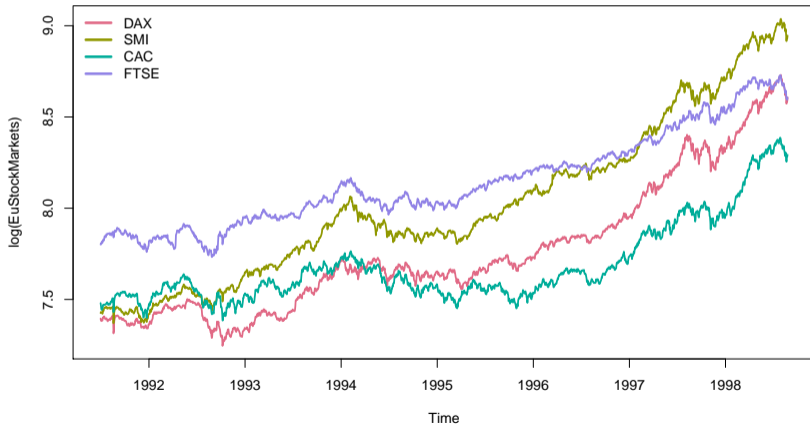
- HCL palette functions return hex color vector.
- Typically passed to `col =` argument of base plotting functions.

## ggplot2:

- Scales of type `scale_<aesthetic>_<datatype>_<colorscale>()`.
- `<aesthetic>` is `fill` or `color/colour`.
- `<datatype>` is `discrete` or `continuous`.
- `<colorscale>` is `qualitative`, `sequential`, `diverging`, or `divergingx`.

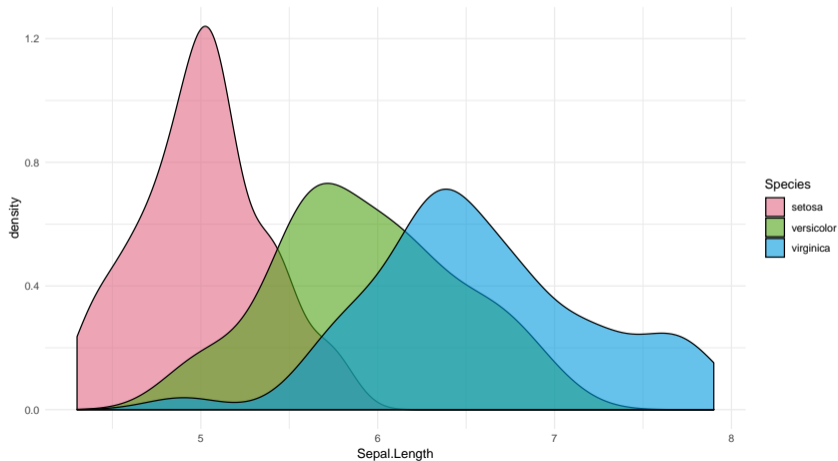
# Statistical graphics: Base

```
R> q4 <- qualitative_hcl(4, palette = "Dark 3")  
R> plot(log(EuStockMarkets), plot.type = "single", col = q4, lwd = 2)  
R> legend("topleft", colnames(EuStockMarkets), col = q4, lwd = 3, bty = "n")
```



# Statistical graphics: ggplot2

```
R> library("ggplot2")  
R> ggplot(iris, aes(x = Sepal.Length, fill = Species)) + geom_density(alpha = 0.6) +  
+   scale_fill_discrete_qualitative(palette = "Dark 3")
```



# Visualization and assessment

**Visualizations:** Based on vector of colors.

- `swatchplot()`: Color swatches.
- `specplot()`: Spectrum of HCL and/or RGB trajectories.
- `hclplot()`: Trajectories in 2-dimensional HCL space projections.
- `demoplot()`: Illustrations of typical (and simplified) statistical graphics.

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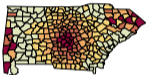
**Emulation:** Color vision deficiency.

- `deutan()`: Deuteranopia (green deficient).
- `protan()`: Protanopia (red deficient).
- `tritan()`: Tritanopia (blue deficient).

# Visualization and assessment: demoplot()

```
R> cl <- sequential_hcl(5, palette = "Heat")  
R> demoplot(cl, type = "...")
```

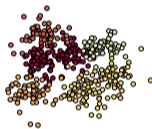
map



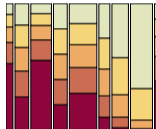
heatmap



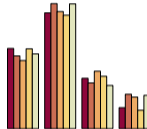
scatter



spine



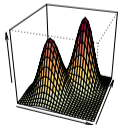
bar



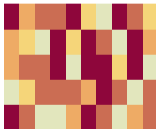
pie



perspective



mosaic



lines





# Color apps

**Facilitate exploration:** Graphical user interfaces as shiny apps.

- *Palette constructor:* `choose_palette()` or `hclwizard()` (also in `tcltk`).
- *Color picker:* `choose_color()` or `hcl_color_picker()`.
- *Color vision deficiency emulator:* `cvd_emulator()`.

**Online versions:** <http://hclwizard.org/>

# Color apps: choose\_palette() / hclwizard()

Mozilla Firefox

File Edit View History Bookmarks Tools Help

127.0.0.1:5604/ x +

127.0.0.1:5604

Search

Base Options

Type of palette  
Advanced: Sequential (single-hue)

Base color scheme  
Blues 3

Example  
Heatmap

Control Options

Reverse  
 Correct colors  
 Dark mode  
 Desaturated

Vision

Normal  
 Deutan  
 Protan  
 Tritan

Color Settings

HUE 1: 240 SET

CHROMA 1: 50 SET

MAX CHROMA: 90 SET

LUMN. 1: 20 SET

LUMN. 2: 95 SET

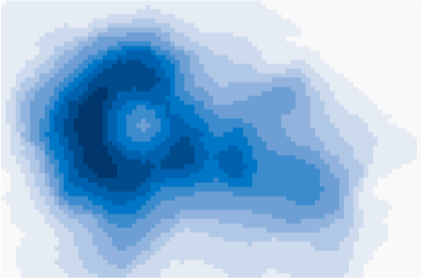
POWER 1: 1.2 SET

POWER 2: 1.4 SET

NUMBER: 11 SET

Return to R

Example Plot Spectrum Color Plane Export Info



R colorspace 1.4.5

# Color apps: choose\_color() / hcl\_color\_picker()

The screenshot shows a web application for color selection. On the left, there are three sliders: Hue (set to 270), Chroma (set to 50), and Luminance (set to 60). Below these is a text input for the RGB hex color, currently showing #9189C7. A 'Selected color' bar shows a purple color. At the bottom left are buttons for 'Pick', 'Unpick', 'Clear', and 'Return to R', along with a 'Dark mode' checkbox.

The main area features a 'Luminance-Chroma plane' diagram. The y-axis is Luminance (0-100) and the x-axis is Chroma (0-125). A color gradient is shown, with a small circle indicating the current color. Below the diagram are three horizontal color bars: Hue (0-360), Chroma (0-150), and Luminance (0-100), each with a small circle indicating the current value.

At the bottom, a 'Color palette' shows four color swatches: #E2E2E2, #B9B5D5, #9189C7, and #5F4FB1. The text 'R colorspace 1.4.0' is visible in the bottom right corner.

# Color apps: cvd\_emulator()

Mozilla Firefox


File Edit View History Bookmarks Tools Help

127.0.0.1:5604/ x +

127.0.0.1:5604

Upload Original Desaturated Deuteranope Protanope Tritanope


All Info



## Severity

0 10 20 30 40 50 60 70 80 90 100


Different levels of severity for the color vision deficiency can be emulated. A value of 100% means maximum deficiency, a value of 0% means no deficiency at all. This value has to be adjusted before uploading the image.



## Upload Image

Browse... No file selected

Select an image from your local disc (PNG/JPG/JPEG) for which the color vision deficiency should be emulated. Please note that the file size is limited to 50.0 Megabyte.



© colorspace 1.4.0

Mozilla Firefox

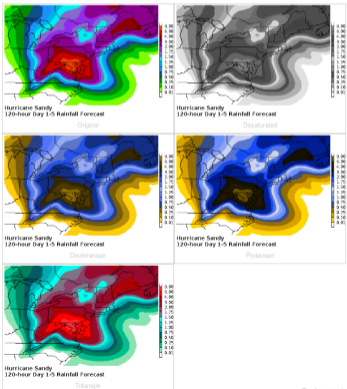
File Edit View History Bookmarks Tools Help

127.0.0.1:5604/ x +

127.0.0.1:5604

Upload Original Desaturated Deuteranope Protanope Tritanope

All Info



The image displays a 3x2 grid of rainfall forecast maps for Hurricane Sandy, 120-hour Day 1-5. Each map is labeled 'Original' or with a specific color vision deficiency type: 'Desaturated', 'Deuteranope', 'Protanope', and 'Tritanope'. The maps show rainfall intensity with a color scale from 0 to 100. The 'Original' map uses a rainbow color scale. The 'Desaturated' map is in grayscale. The 'Deuteranope' map uses a blue-to-yellow color scale. The 'Protanope' map uses a blue-to-cyan color scale. The 'Tritanope' map uses a red-to-cyan color scale. Each map includes a vertical color scale legend on its right side.

Hurricane Sandy 120-hour Day 1-5 Rainfall Forecast

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Hurricane Sandy 120-hour Day 1-5 Rainfall Forecast

© colorspace 1.4.0

# References

Zeileis A, Fisher JC, Hornik K, Ihaka R, McWhite CD, Murrell P, Stauffer R, Wilke CO (2019). “colorspace: A Toolbox for Manipulating and Assessing Colors and Palettes.” arXiv:1903.06490, arXiv.org E-Print Archive. <http://arxiv.org/abs/1903.06490>

Zeileis A, Hornik K, Murrell P (2009). “Escaping RGBland: Selecting Colors for Statistical Graphics.” *Computational Statistics & Data Analysis*, **53**, 3259–3270. doi:10.1016/j.csda.2008.11.033.

Stauffer R, Mayr GJ, Dabernig M, Zeileis A (2015). “Somewhere over the Rainbow: How to Make Effective Use of Colors in Meteorological Visualizations.” *Bulletin of the American Meteorological Society*, **96**(2), 203–216. doi:10.1175/BAMS-D-13-00155.1