Chasing rainbows: Revisiting the prevalence of the rainbow color scheme in scientific publications

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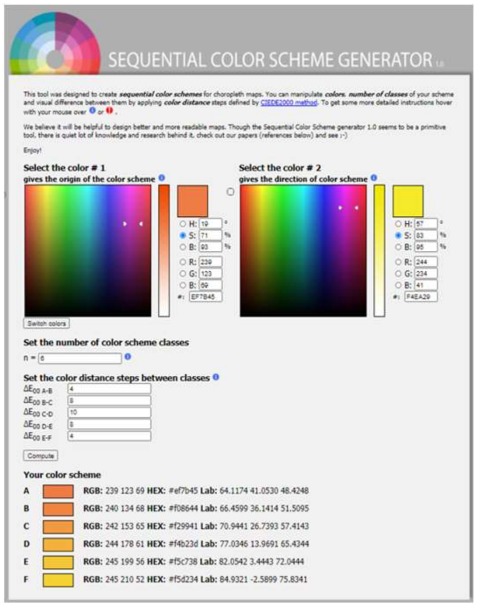
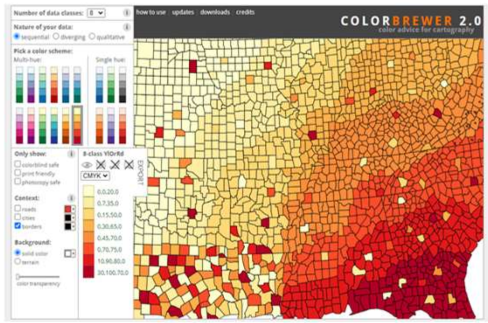
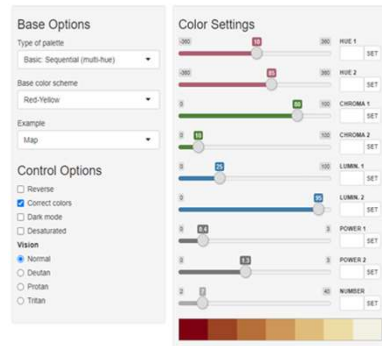
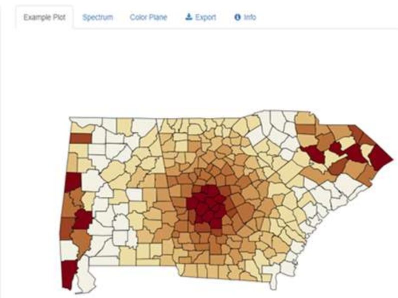
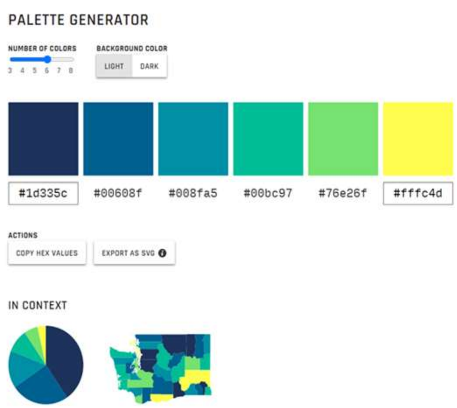
40th NACIS annual meeting - October 15th 2020

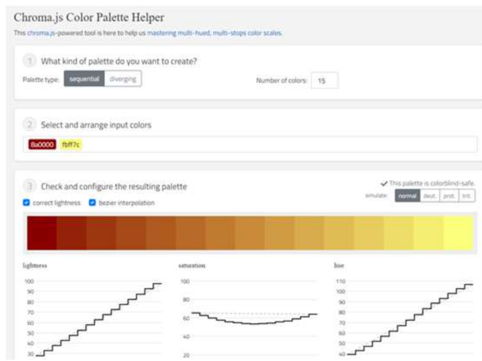

SEQUENTIAL COLOR SCHEME GENERATOR
Select the color # 1
gives the origin of the color scheme
Select the color # 2
gives the direction of color scheme
Set the number of color scheme classes
Set the color distance steps between classes
Compute
Your color scheme
RGB: 239 123 69 HEX: #ef7b45 Lab: 64.1174 41.0530 48.4248
RGB: 240 134 68 HEX: #f08644 Lab: 66.4599 36.1414 51.5095
RGB: 242 153 65 HEX: #f29941 Lab: 70.9441 26.7393 57.4143
RGB: 244 178 61 HEX: #f4b23d Lab: 77.0346 13.9691 65.4344
RGB: 245 199 56 HEX: #f5c738 Lab: 82.0542 3.4443 72.0444
RGB: 245 210 52 HEX: #f5d234 Lab: 84.9321 -2.5899 75.8341

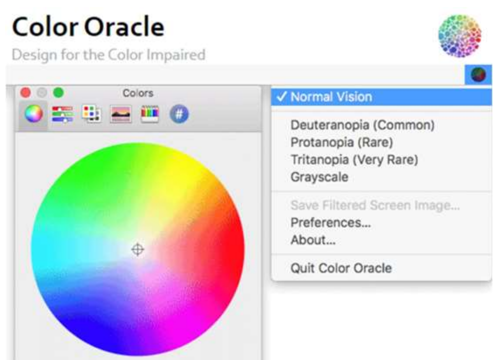

COLORBREWER 2.0
color advice for cartography

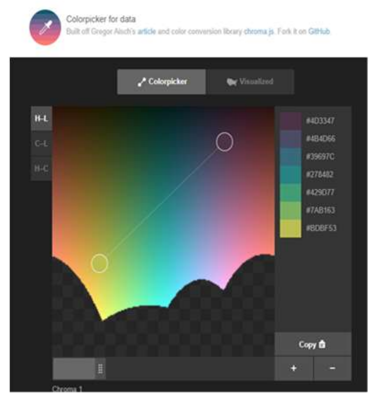

Base Options
Type of palette
Basic: Sequential (multi-hue)
Base color scheme
Red-Yellow
Example
Map
Control Options
Reverse
Correct colors
Dark mode
Desaturated
Vision
Normal
Deutan
Protan
Tritan
Color Settings


Example Plot
Spectrum
Color Plane
Export
Info


PALETTE GENERATOR
NUMBER OF COLORS
BACKGROUND COLOR
LIGHT
DARK
#1d335c
#00608f
#008fa5
#00bc97
#76e26f
#fffc4d
ACTIONS
COPY HEX VALUES
EXPORT AS SVG
IN CONTEXT


Chroma.js Color Palette Helper
What kind of palette do you want to create?
Select and arrange input colors
Check and configure the resulting palette


Color Oracle
Design for the Color Impaired
Colors
✓ Normal Vision
Deuteranopia (Common)
Protanopia (Rare)
Tritanopia (Very Rare)
Grayscale
Save Filtered Screen Image...
Preferences...
About...
Quit Color Oracle


Colorpicker for data
Colorpicker
Visualized
#4D3347
#484D66
#39697C
#278482
#429D77
#7AB163
#BDBF53
Copy


Colorpicker for data
Colorpicker
Visualized

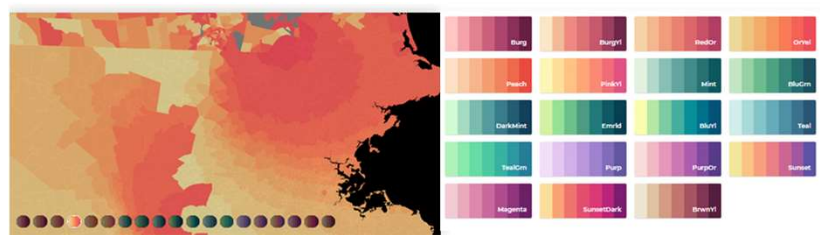
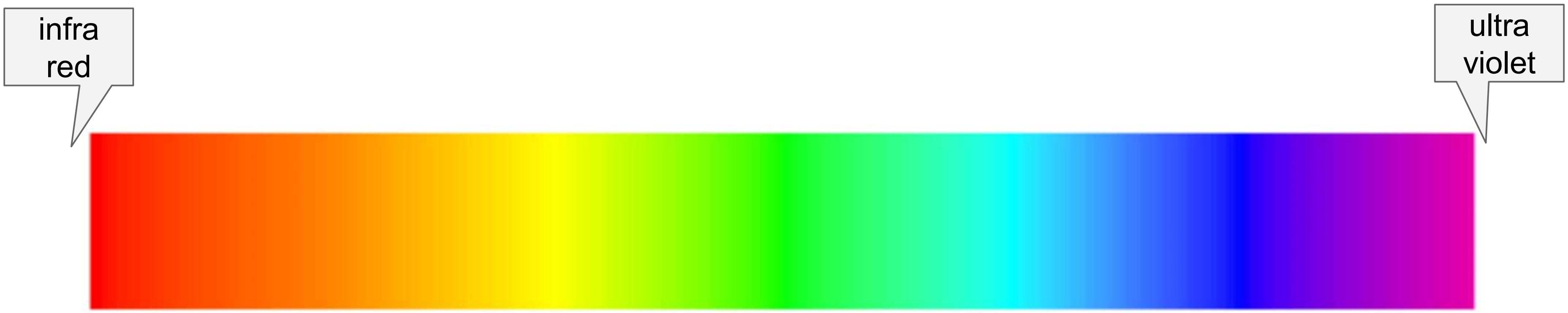

Burg
BurgYl
RedOr
OrYel
Peach
PinkYl
Mint
BluGrn
DarkMint
Emrld
BluYl
Teal
TealGrn
Purp
PurpOr
Sunset
Magenta
SunsetDark
BrwnYl

Image: https://www.metoffice.gov.uk/binaries/content/gallery/metofficegovuk/hero-images/weather/optical-effects/rainbows/double-rainbow.jpg



Varies **hues** via a gradation based on the visible spectrum

(and it magically appears when it rains on a sunny day)

as beautiful as rainbows are, and we love them for all kinds of reasons,
we heard they are not good for visualizing (quantitative) data.

perhaps you heard it too?

‘Good color scheme’ standards (Levkowitz and Herman 1992)

Ability to present:

- order
- uniformity
- representative distance
- do not create false boundaries

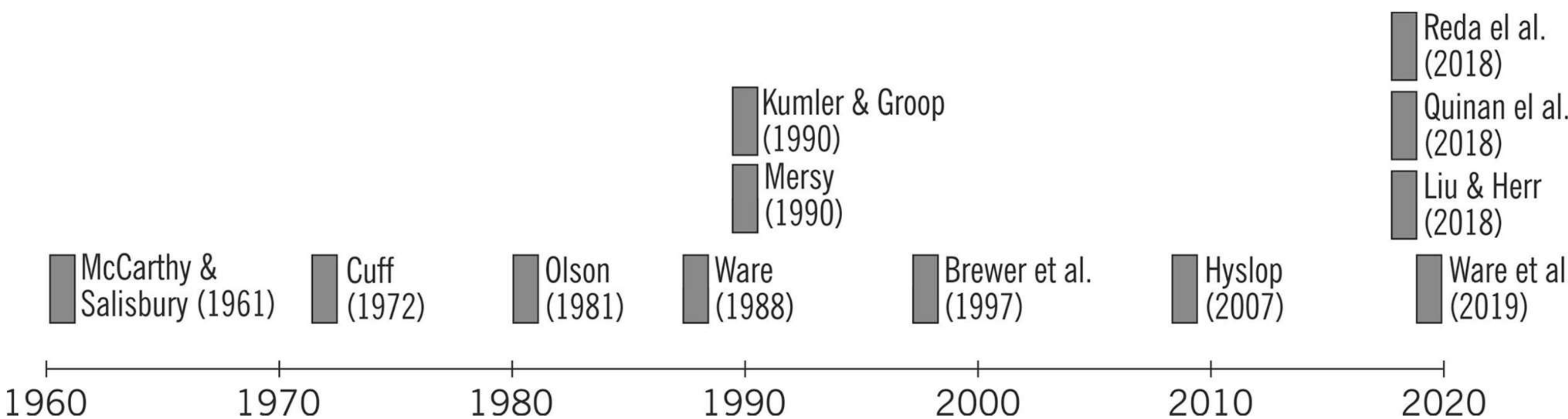
‘Good color scheme’ standards (Levkowitz and Herman 1992)

Ability to present

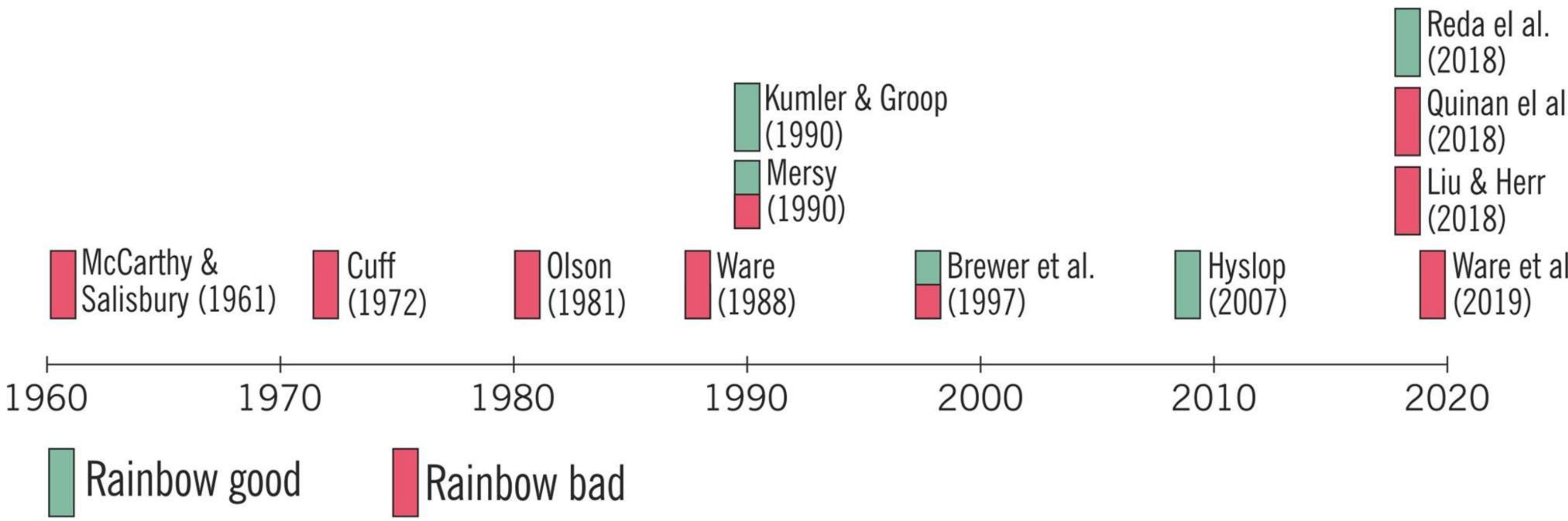
- x order (*e.g.,* Monmonier 1991, MacEachren 1995, Munzner 2014)
- x uniformity (*e.g.,* Moreland 2016)
- x representative distance (*e.g.,* Rogowitz, Treinish, Bryson, 1996)
- x do not create false boundaries (*e.g.,* Rogowitz, Treinish, Bryson, 1996)
  - \+ x should facilitate vision for all (*e.g.,* Moreland 2016)

Image https://tinyurl.com/y24v9ucg

User studies examining the rainbow scheme (RC) 1/3

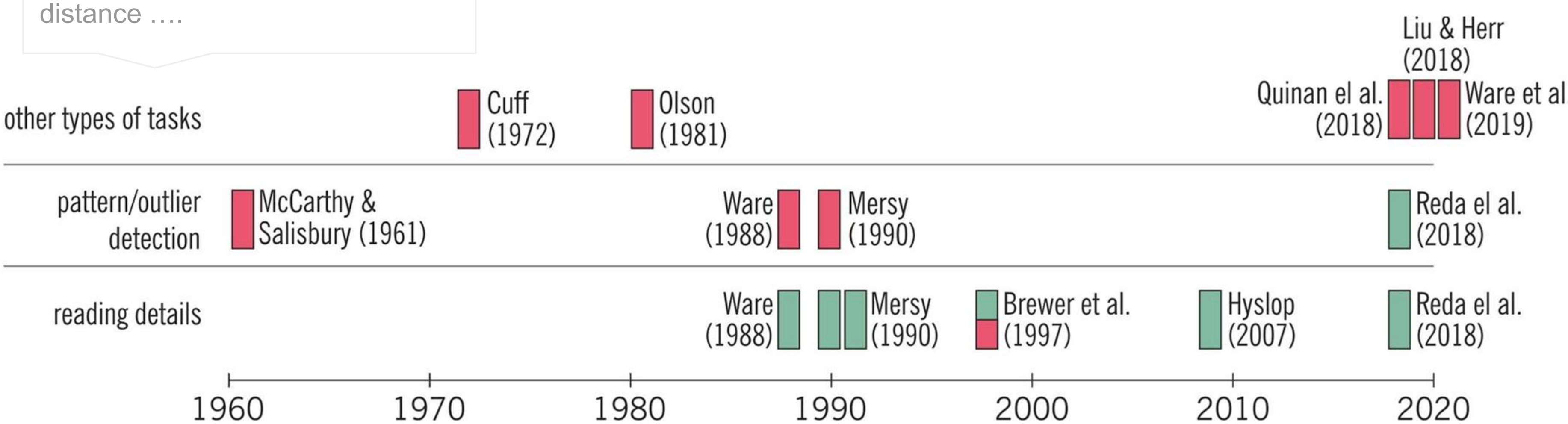


User studies examining the RC 2/3



User studies examining the RC 3/3

ordering, false boundaries, color distance ….



… so, understood. The RC not ideal in vis. (… sorry, Dash)

- ➡ But does it matter? We all learned this for so many years!
  Do people (still) use the RC in visualizations?

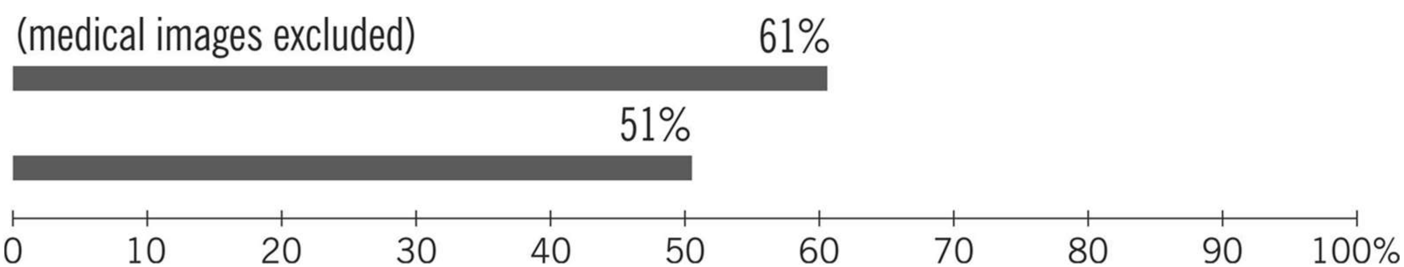
Prevalence of the RC in scientific publications

- Brewer (**1997**) studied *Nature*, *Science* and *Discover*, and concluded:

  *"**Spectral schemes are standard choices**, but sequential schemes with hue transitions and two-hue diverging schemes are used."*

- 10 years later, Borland & Taylor (**2007**) analysed

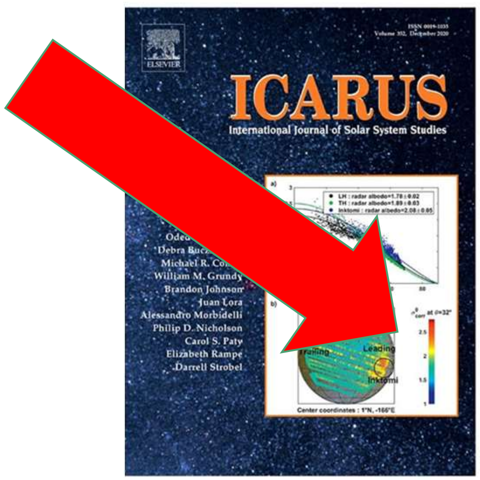
  IEEE Visualization Conference proceedings 2001 through 2005



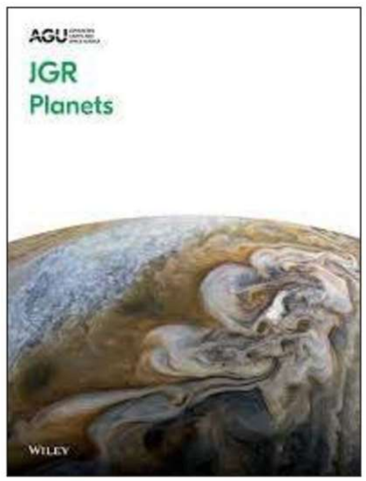
… a bit more than 10 years passed, no one else was looking, so we decided to check!

Journals we checked

Planetary Science

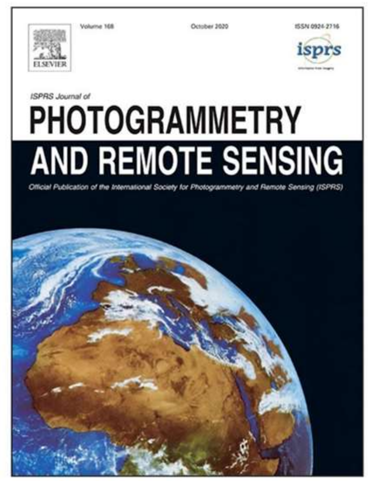


IF 3.51

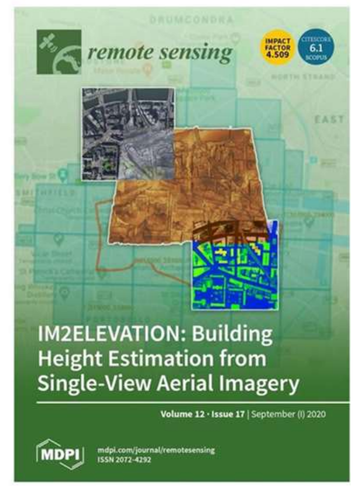


IF 3.71

Remote Sensing



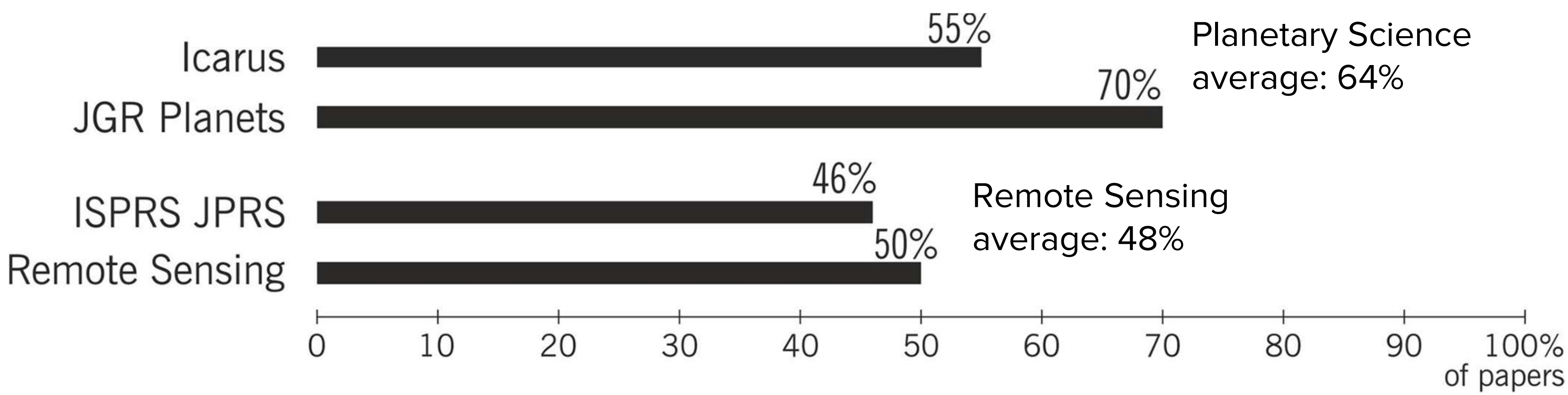
IF 7.32



IF 4.51

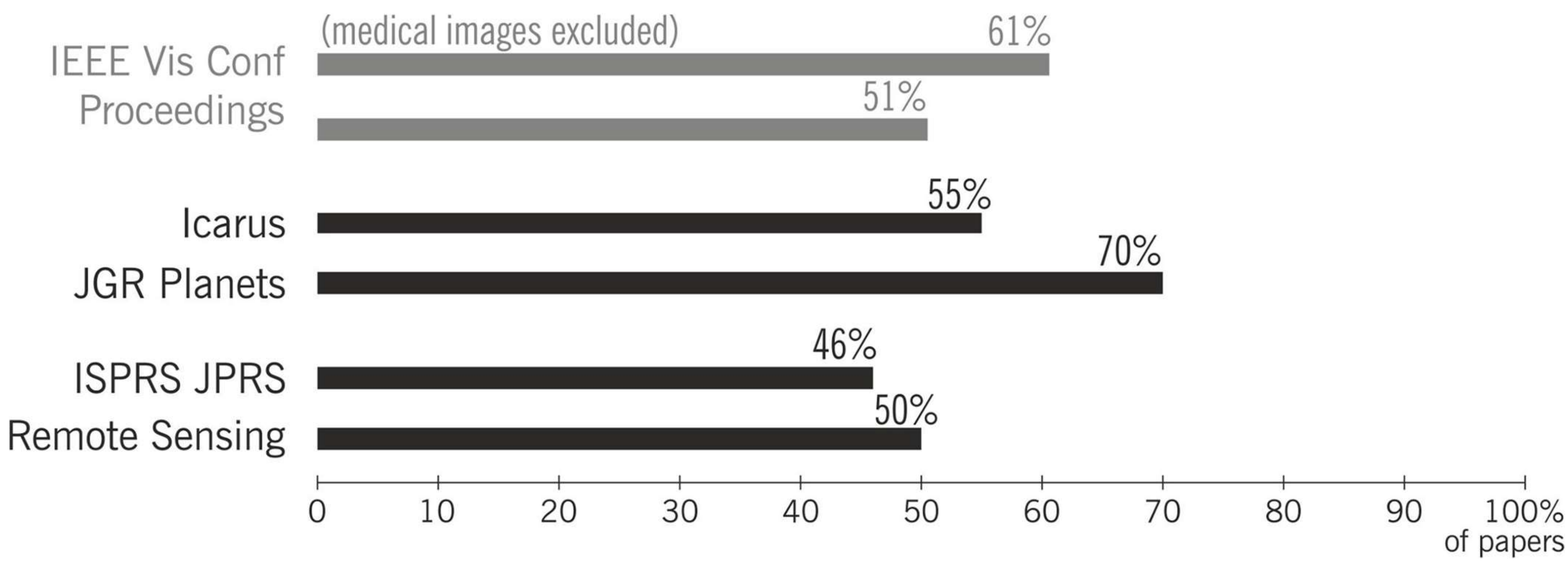
355 papers from late 2019 & early 2020

Results

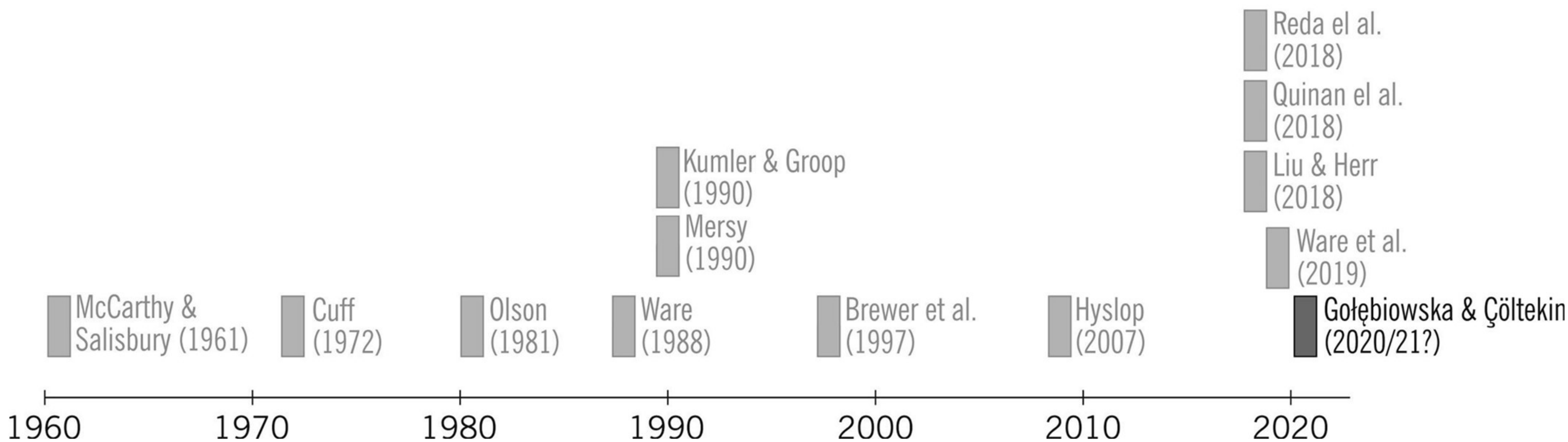


Icarus
JGR Planets
ISPRS JPRS
Remote Sensing
55%
70%
46%
50%
Planetary Science average: 64%
Remote Sensing average: 48%
0
10
20
30
40
50
60
70
80
90
100% of papers

Results



(medical images excluded)
61%
IEEE Vis Conf Proceedings
51%
55%
Icarus
70%
JGR Planets
46%
ISPRS JPRS
50%
Remote Sensing
0
10
20
30
40
50
60
70
80
90
100%
of papers



McCarthy & Salisbury (1961)
Cuff (1972)
Olson (1981)
Ware (1988)
Kumler & Groop (1990)
Mersy (1990)
Brewer et al. (1997)
Hyslop (2007)
Reda el al. (2018)
Quinan el al. (2018)
Liu & Herr (2018)
Ware et al. (2019)
Gołębiowska & Çöltekin (2020/21?)
1960
1970
1980
1990
2000
2010
2020

rainbow scheme

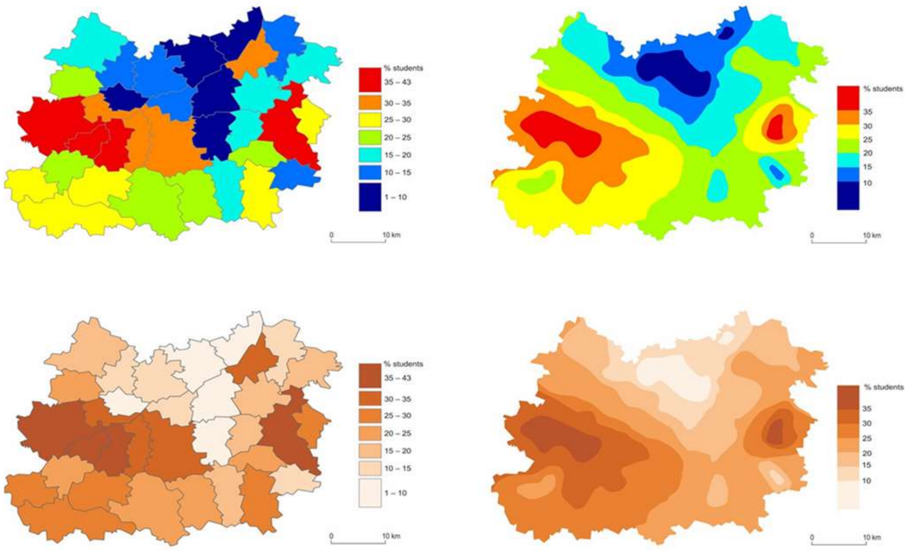
versus

sequential ColorBrewer ‘7 class oranges’

we analysed

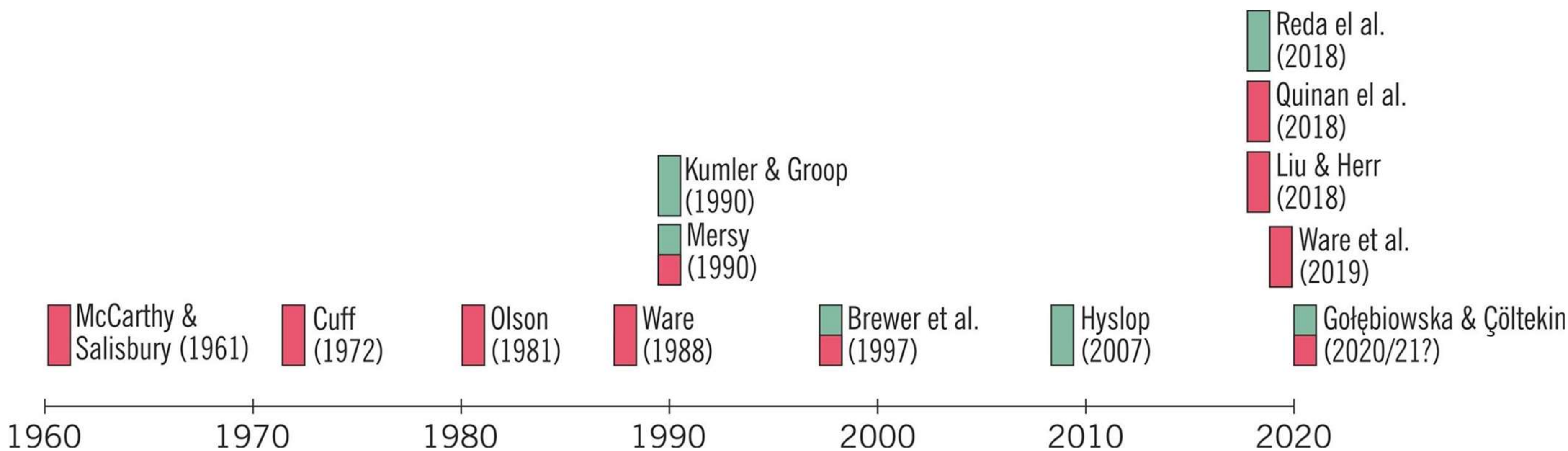
response accuracy • response time • rating of difficulty

across 11 tasks and two map types



between-user study with 544 participants,

high school students from 22 schools across Poland


Reda el al.
(2018)
Quinan el al.
(2018)
Liu & Herr
(2018)
Ware et al.
(2019)
Kumler & Groop
(1990)
Mersy
(1990)
McCarthy &
Salisbury (1961)
Cuff
(1972)
Olson
(1981)
Ware
(1988)
Brewer et al.
(1997)
Hyslop
(2007)
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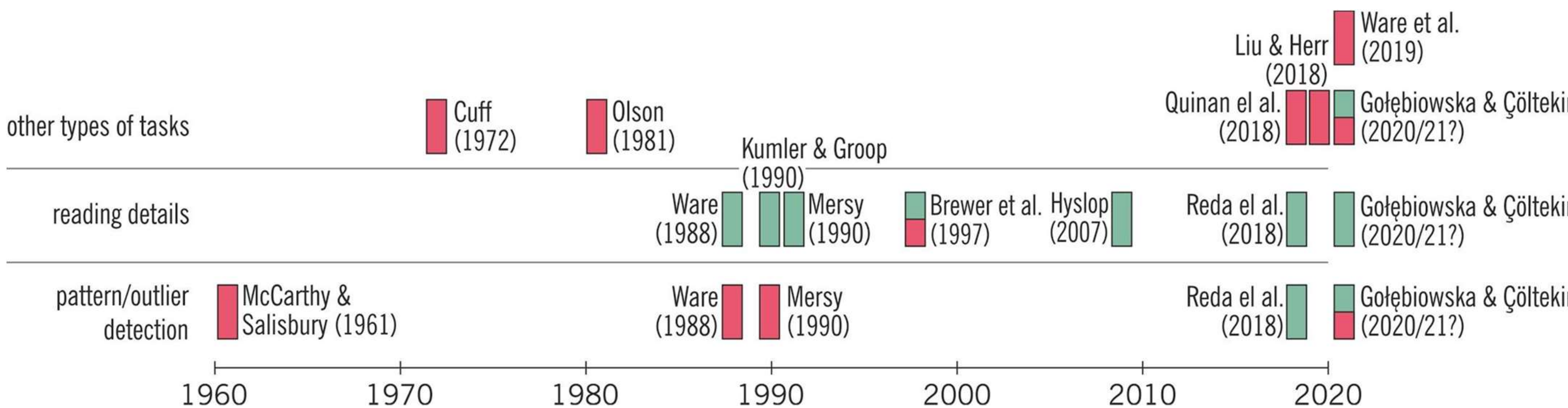

other types of tasks
reading details
pattern/outlier detection
Cuff (1972)
Olson (1981)
Kumler & Groop (1990)
Liu & Herr (2018)
Ware et al. (2019)
Quinan el al. (2018)
Gołębiowska & Çöltekin (2020/21?)
Ware (1988)
Mersy (1990)
Brewer et al. (1997)
Hyslop (2007)
Reda el al. (2018)
Gołębiowska & Çöltekin (2020/21?)
McCarthy & Salisbury (1961)
Ware (1988)
Mersy (1990)
Reda el al. (2018)
Gołębiowska & Çöltekin (2020/21?)
1960
1970
1980
1990
2000
2010
2020

Take away

- Rainbow scheme research is still highly relevant
    - 50-70% of scientific publications still use the rainbow colors!
- Rainbows are lovely, and they are OK for some tasks
    - but they do impair user performance for some others

For now, maybe avoid it, if you *really* want to use this color scale,
inform yourself well about the consequences and beware of the task type

online tools:

Sequential Scheme Generator http://eyetracking.upol.cz/color/ by Brychtová, A., Doležalová, J., & Štrubl, O.

Color Brewer 2.0. Color advice for cartography. http://colorbrewer2.org/ by Brewer, C. A., Harrower, M., Sheesley, B., Woodruff, A., & Heyman, D.

Chroma.js Color Palette Helper. https://vis4.net/palettes/ by Aisch, G.

Color Oracle https://colororacle.org/ by Jenny, B., & Kelso, N. V.

Colorgorical http://vrl.cs.brown.edu/color by Gramazio, C. C., Laidlaw, D. H., & Schloss, K. B.

hclwizard http://hclwizard.org/ by Stauffer, R., Mayr, G. J., Dabernig, M., & Zeileis, A.

Carto-colors https://carto.com/carto-colors/

Color Picker for data http://tristen.ca/hcl-picker by Brown, T.

Opinions about (rainbow) color use:

Levkowitz, H., & Herman, G. T. (1992). Scales for Image Data. In Calphad: Computer Coupling of Phase Diagrams and Thermochemistry, Vol. 12, Issue 1.

MacEachren, A. M. (1995). How maps work: Representation, visualization, and design. Guilford.

Monmonier, M. (1991). How to lie with maps. The University of Chicago Press.

Moreland, K. (2016). Why we use bad color maps and what you can do about it. Human Vision and Electronic Imaging 2016, HVEI 2016, 262–267.

Munzner, T. (2014). Visualization analysis and design (1st ed.). CRC Press.

Rogowitz, B. E., Treinish, L. A., & Bryson, S. (1996). How not to lie with visualization. Computers in Physics, 10(3), 268–273.

Empirical evaluations of RC:

Brewer, C. A., MacEachren, A. M., Pickle, L. W., & Herrmann, D. (1997). Mapping mortality: Evaluating color schemes for choropleth maps. Annals of the Association of American Geographers, 87(3), 411–438.

Cuff, D. J. (1972). The Magnitude Message: A Study of the Effectiveness of Color Sequences on Quantitative Maps. The Pennsylvania State University.

Hyslop, M. D. (2007). A Comparison of User Performance on Spectral Colour and Grayscale Continuous-Tone Maps. Michigan State University.

Kumler, M. P., & Groop, R. E. (1990). Continuous-tone mapping of smooth surfaces. Cartography and Geographic Information Systems, 17(4), 279–289.

Liu, Y., & Heer, J. (2018). Somewhere over the rainbow: An empirical assessment of quantitative colormaps. Conference on Human Factors in Computing Systems - Proceedings, 2018-April.

McCarty, H. H., & Salisbury, N. E. (1961). Visual comparison of isopleth maps as a means of determining correlations between spatially distributed phenomena. Studies in Geography No. 3.

Mersy, J. E. (1990). Colour and Thematic Map Design: The Role of Colour Scheme and Map Complexity in Choropleth Map Communication. Cartographica: The International Journal for Geographic Information and Geovisualization, 27(3), 1–167.

Olson, J. M. (1981). Spectrally encoded two-variable maps. Annals of the Association of American Geographers, 71(2), 259–276.

Quinan, P. S., Padilla, L. M., Creem-Regehr, S. H., & Meyer, M. (2019). Examining implicit discretization in spectral schemes. Computer Graphics Forum, 38(3), 363–374.

Reda, K., Nalawade, P., & Ansah-Koi, K. (2018). Graphical perception of Continuous quantitative maps: The effects of spatial frequency and colormap design. Conference on Human Factors in Computing Systems - Proceedings, 2018-April.

Ware, C. (1988). Color/Maps Color Sequences for Univariate Maps: Theory, Experiments, and Principles. IEEE Computer Graphics and Applications, 8(5), 41–49.

Ware, C., Turton, T. L., Bujack, R., Samsel, F., Shrivastava, P., & Rogers, D. H. (2019). Measuring and Modeling the Feature Detection Threshold Functions of Colormaps. IEEE Transactions on Visualization and Computer Graphics, 25(9), 2777–2790.

This work was supported by the project ”Evaluation of cartographic presentation methods in the context of map perception and effectiveness of visual transmission”, funded by the Polish National Science Centre, [Grant number UMO-2016/23/B/HS6/03846].