Data Visualizations:
Creation & Consumption

PsyF First Year Fest ‘24
Regina Lisinker

Table of contents

01 What is Data Visualization?

02 Current Work

03 End Goal

01

What is Data Visualization?

What is Data Visualization?

- Simply: a graphic or visual representation of data
- Goes by many names:
  - Graphical representation
  - Information visualization
  - Visual data communication
- The goal: facilitate understanding

(Anouncia et al., 2020; Bolch & Crippen, 2022)

What is Data Visualization?

- “Data visualizations can also play a critical role when it is time to disseminate and communicate” (Azzam et al., 2013)
- “Proper data visualization facilitates the recognition of patterns and relationships to communicate a message in a more compelling and interesting way” (Archambault et al., 2015)
- While “ineffectively designed visualizations can cause confusion, misunderstanding, or even distrust—especially among viewers with low graphical literacy” (Franconeri et al., 2021)

What is Data Visualization?

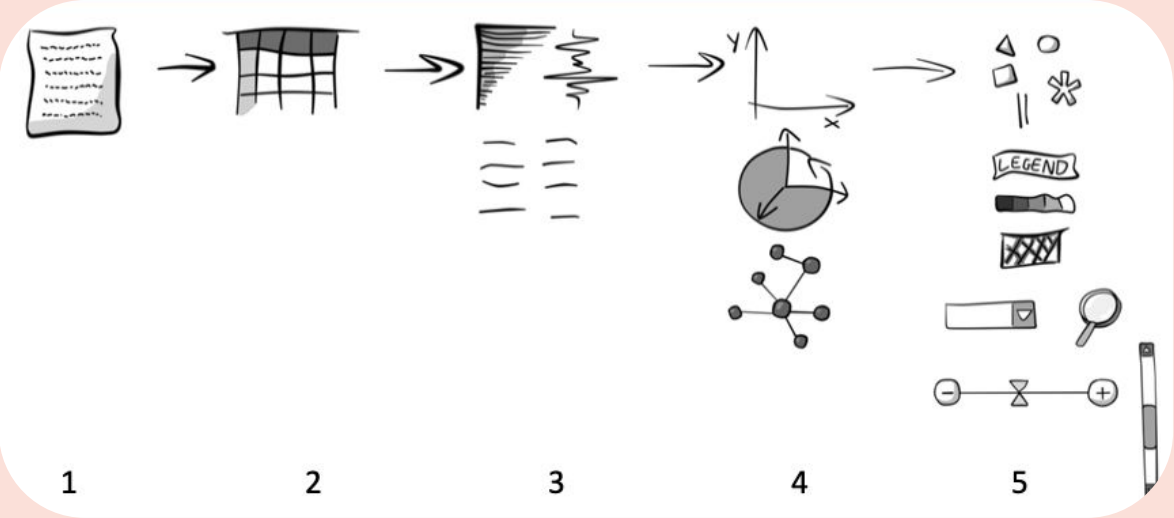


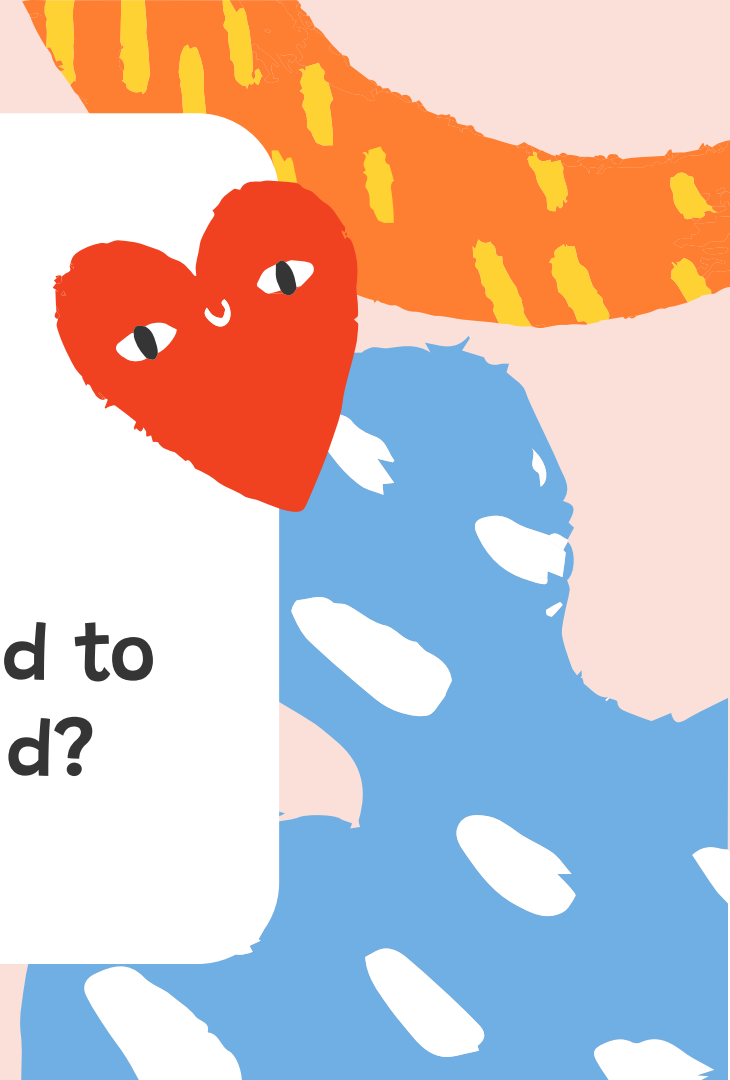
Figure 1. The five phases of visualization process: data gathering, processing, preparation, reduction and visual layout design. (Osinska, 2018)

- When data visualization is defined as a process, consumption is rarely included :(

02

Current Work:

Are creators encouraged to keep consumers in mind?



What kind of advice is out there for creators of data visualization?

Tips: do's and don'ts for data visualization

Do's:

- ✓ Pass the squint test: Is the information conveyed without reading any text? Does the right color pop out? Are the labels clear? Try printing out your visualization in black and white, or make a copy in gray scale to check for visibility (Clayton, 2014).
- ✓ Show restraint and limit the data to your main point so you do not overwhelm the audience (Dando, 2014, p. 74).
- ✓ Organize: group, prioritize and sequence data to help viewers understand.
- ✓ Provide a key to your visualization if necessary for the viewer to understand your data (Dando, 2014, p. 81).
- ✓ Have a colleague preview your data visualization for clarity (Dando, 2014, pp. 80-81).
- ✓ Round to the nearest significant digit for clarity in labels, but use decimal places for accuracy in calculating and plotting the graphs (Wong, 2010, p. 22).
- ✓ Frame your data in a context that your audience can relate to and offer relevant reference points (Dando, 2014, p. 77).
- ✓ Use colors sparingly and to help convey meaning rather than for decoration (Dando, 2014, p. 81). Similarly, use as few font styles as

Don'ts

- × Do not manipulate data to tell a story it does not actually tell. Tufte (2001, pp. 55-77) calls this "graphical integrity".
- × Do not use 3D or a "blow apart" effect – this reduces comprehension and makes it hard to compare elements (Few, 2012, p. 197).
- × Visualize all of the important relationships and make large data sets coherent (Tufte, 2001, p. 13).
- × Do not put a box around your graph. This is an unnecessary ink that will visually distract the viewer (Tufte, 2001, p. 127).
- × Do not use red/green or blue/yellow combinations because the lack of contrast in lightness makes it unreadable for the color-blind (Wong, 2010, p. 44).

# of advice is out reators of data lization?

Tips: do's and don'ts for data visualization

Do's:

- ✓ Pass the squint test: Is the information conveyed without reading any text? Does the right color pop out? Are the labels clear? Try printing out your visualization in black and white, or make a copy in gray scale to check for visibility (Clayton, 2014).
- ✓ Show restraint and limit the data to your main point so you do not overwhelm the audience (Dando, 2014, p. 74).
- ✓ Organize: group, prioritize and sequence data to help viewers understand.
- ✓ Provide a key to your visualization if necessary for the viewer to understand your data (Dando, 2014, p. 81).
- ✓ Have a colleague preview your data visualization for clarity (Dando, 2014, pp. 80-81).
- ✓ Round to the nearest significant digit for clarity in labels, but use decimal places for accuracy in calculating and plotting the graphs (Wong, 2010, p. 22).
- ✓ Frame your data in a context that your audience can relate to and offer relevant reference points (Dando, 2014, p. 77).
- ✓ Use colors sparingly and to help convey meaning rather than for decoration (Dando, 2014, p. 81). Similarly, use as few font styles as

Don'ts

- × Do not manipulate data to t story it does not actually tell. ' (2001, pp. 55-77) calls "graphical integrity".
- × Do not use 3D or a " apart" effect – this reduces comprehension and makes it hard to compare elements (Few, 2012, p. 197).
- × Visualize all of the important relationships and make large data sets coherent (Tufte, 2001, p. 13).
- × Do not put a box around your graph. This is an unnecessary ink that will visually distract the viewer (Tufte, 2001, p. 127).
- × Do not use red/green or blue/yellow combinations because the lack of contrast in lightness makes it unreadable for the color-blind (Wong, 2010, p. 44).

Principle #4 Colors *Always* Mean Something

The use of color in visualization can be incredibly powerful, and there is rarely a reason not to use color. Even if authors do not wish to pay for color figures in print, most journals still permit free color figures in digital formats. In a large study[20] of what

Principle #5 Include Uncertainty

Not only is uncertainty an inherent part of understanding most systems, failure to include uncertainty in a visual can be misleading. There exist two primary challenges with including uncertainty in visuals: failure to include uncertainty and misrep-

reators of data
lization?

Tips: do's and don'ts for data visualization

Do's:

- ✓ Pass the squint test: Is the information conveyed without reading any text? Does the right color pop out? Are the labels clear? Try printing out your visualization in black and white, or make a copy in gray scale to check for visibility (Clayton, 2014).
- ✓ Show restraint and limit the data to your main point so you do not overwhelm the audience (Dando, 2014, p. 74).
- ✓ Organize: group, prioritize and sequence data to help viewers understand.
- ✓ Provide a key to your visualization if necessary for the viewer to understand your data (Dando, 2014, p. 81).
- ✓ Have a colleague preview your data visualization for clarity (Dando, 2014, pp. 80-81).
- ✓ Round to the nearest significant digit for clarity in labels, but use decimal places for accuracy in calculating and plotting the graphs (Wong, 2010, p. 22).
- ✓ Frame your data in a context that your audience can relate to and offer relevant reference points (Dando, 2014, p. 77).
- ✓ Use colors sparingly and to help convey meaning rather than for decoration (Dando, 2014, p. 81). Similarly, use as few font styles as

Don'ts

- × Do not manipulate data to t story it does not actually tell. (2001, pp. 55-77) calls "graphical integrity".
- × Do not use 3D or a " apart" effect – this reduces comprehension and makes it hard to compare elements (Few, 2012, p. 197).
- × Visualize all of the important relationships and make large data sets coherent (Tufte, 2001, p. 13).
- × Do not put a box around your graph. This is an unnecessary ink that will visually distract the viewer (Tufte, 2001, p. 127).
- × Do not use red/green or blue/yellow combinations because the lack of contrast in lightness makes it unreadable for the color-blind (Wong, 2010, p. 44).

Principle #4 Colors *Always* Mean Something

The use of color in visualization can be incredibly powerful, and there is rarely a reason not to use color. Even if authors do not wish to pay for color figures in print, most journals still permit free color figures in digital formats. In a large study[20] of what

Principle #5 Include Uncertainty

Not only is uncertainty an inherent part of understanding most systems, failure to include uncertainty in a visual can be misleading. There exist two primary challenges with including uncertainty in visuals: failure to include uncertainty and misrep-

reators of data
lization?

Minimalism

A second important philosophy is that of minimalism. Visualizations can be evaluated in their s ratio, in which signal is the information being conveyed and noise is anything else. The most ef communication maximizes the signal-to-noise ratio by minimizing visual clutter that might inte signal. An extreme version of this argument is that one should justify every single pixel in the v

Tips: do's and don'ts for data visualization

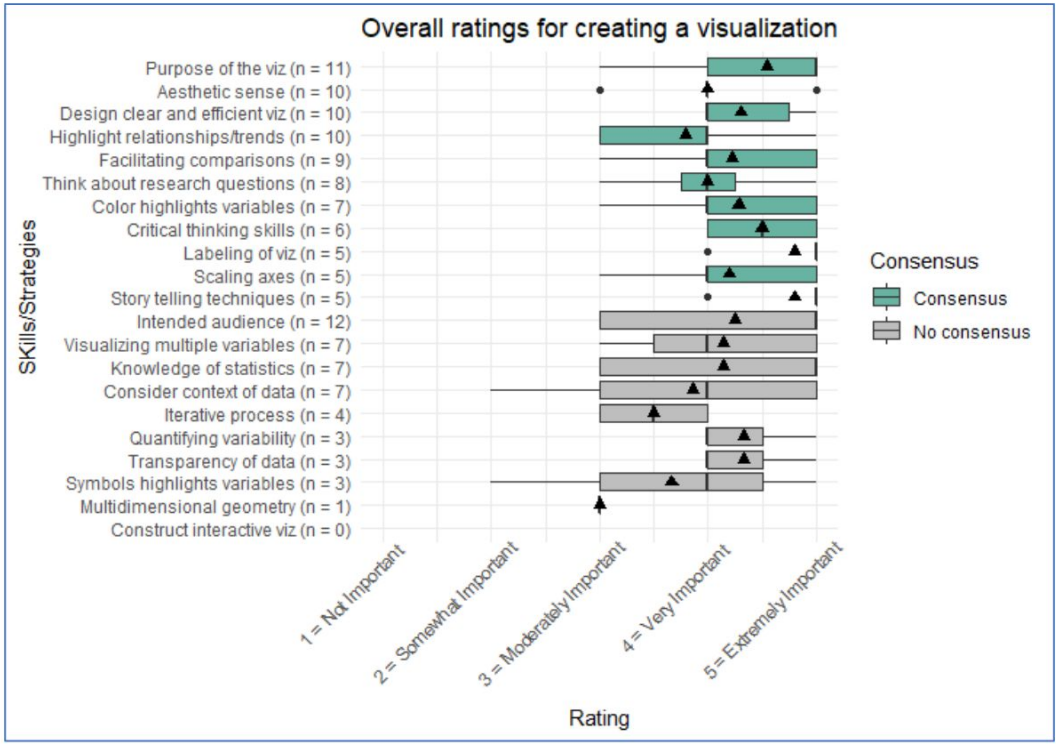
Do's:

- ✓ Pass the squint test: Is the information conveyed without reading any text? Does the right color pop out? Are the labels clear? Try printing out your visualization in black and white, or make a copy in gray scale to check for visibility (Clayton, 2014).
- ✓ Show restraint and limit the data to your main point so you do not overwhelm the audience (Dando, 2014, p. 74).
- ✓ Organize: group, prioritize and sequence data to help viewers understand.
- ✓ Provide a key to your visualization if necessary for the viewer to understand your data (Dando, 2014, p. 81).
- ✓ Have a colleague preview your data visualization for clarity (Dando, 2014, pp. 80-81).
- ✓ Round to the nearest significant digit for clarity in labels, but use decimal places for accuracy in calculating and plotting the graphs (Wong, 2010, p. 22).
- ✓ Frame your data in a context that your audience can relate to and offer relevant reference points (Dando, 2014, p. 77).
- ✓ Use colors sparingly and to help convey meaning rather than for decoration (Dando, 2014, p. 81). Similarly, use as few font styles as

Don'ts

- × Do not manipulate data to t story it does not actually tell. ' (2001, pp. 55-77) calls "graphical integrity".
- × Do not use 3D or a " apart" effect – this reduces comprehension and makes it hard to compare elements (Few, 2012, p. 197).
- × Visualize all of the important relationships and make large data sets coherent (Tufte, 2001, p. 13).
- × Do not put a box around your graph. This is an unnecessary ink that will visually distract the viewer (Tufte, 2001, p. 127).
- × Do not use red/green or blue/yellow combinations because the lack of contrast in lightness makes it unreadable for the color-blind (Wong, 2010, p. 44).

Principle #4 Colors *Always* Mean Something



Note: ▲ indicate mean values for each skill/strategy; "viz" is visualization.

Figure 3. Visualization of Delphi Panel 3 results for creating skills/strategies

Mini

A second important philosophy is that of minimalism. Visualizations can be evaluated in their
ratio, in which signal is the information being conveyed and noise is anything else. The most ef
communication maximizes the signal-to-noise ratio by minimizing visual clutter that might inte
signal. An extreme version of this argument is that one should justify every single pixel in the v

Tips: do's and don'ts for data visualization

Do's:

- ✓ Pass the squint test: Is the information conveyed without reading any text? Does the right color pop out? Are the labels clear? Try printing out your visualization in black and
in gray scal
(Clayton, 2
- ✓ Show restra
your main
overwhelm
2014, p. 74
- ✓ Organize:
sequence
understand.
- ✓ Provide a k
if necessa
understand
2014, p. 81
- ✓ Have a cc
data visu
(Dando, 20
- ✓ Round to
digit for cl
decimal pl
calculating and plotting the graphs (Wong, 2010, p. 22).
- ✓ Frame your data in a context that your audience can relate to and offer relevant reference points (Dando, 2014, p. 77).
- ✓ Use colors sparingly and to help convey meaning rather than for decoration (Dando, 2014, p. 81). Similarly, use as few font styles as

Don'ts

- × Do not manipulate data to
story it does not actually tell.
(2001, pp. 55-77) calls
"graphical integrity".
- × Do not use 3D or a "
apart" effect – this reduces
comprehension and makes it hard
to compare elements (Few, 2012,

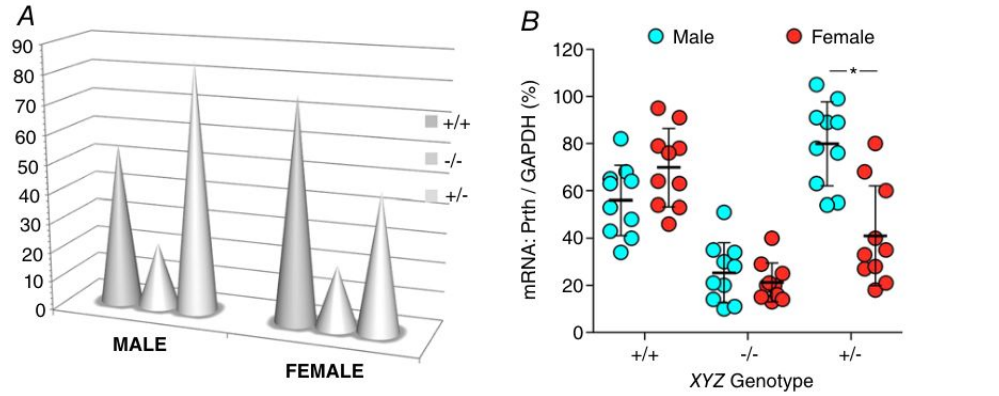
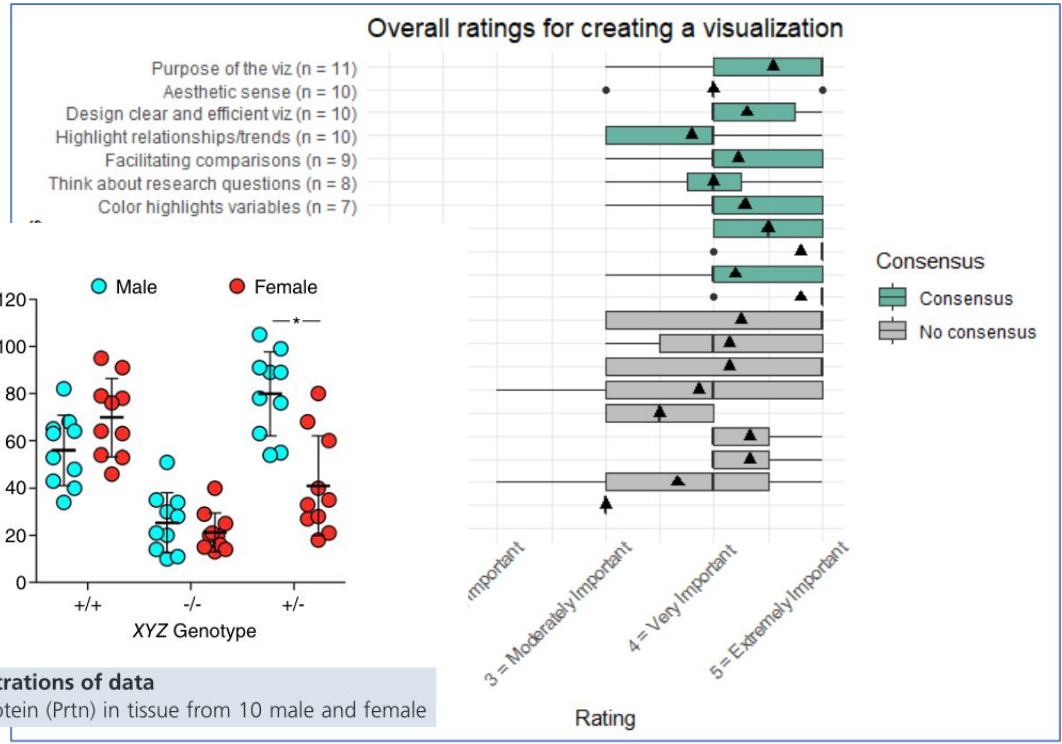


Figure 1. Examples of bad (panel *A*) and good (panel *B*) illustrations of data
The graphs illustrate hypothetical normalized mRNA levels of a protein (Prtn) in tissue from 10 male and female

Principle #4 Colors *Always* Mean Something



Note: ▲ indicate mean values for each skill/strategy; "viz" is visualization.

Figure 3. Visualization of Delphi Panel 3 results for creating skills/strategies

Mini

A second important philosophy is that of minimalism. Visualizations can be evaluated in their
ratio, in which signal is the information being conveyed and noise is anything else. The most ef
communication maximizes the signal-to-noise ratio by minimizing visual clutter that might inte
signal. An extreme version of this argument is that one should justify every single pixel in the v

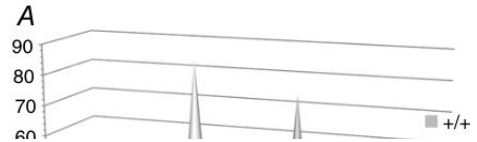
Tips: do's and don'ts for data visualization

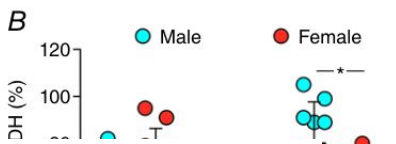
Do's:

- ✓ Pass the squint test: Is the information conveyed without reading any text? Does the right color pop out? Are the labels clear? Try printing out your visualization in black and
in gray scal
(Clayton, 2
- ✓ Show restra
your main
overwhelm
2014, p. 74
- ✓ Organize
sequence
understar
- ✓ Provide a
if neces
understar
2014, p.
- ✓ Have a
data vi
(Dando,
- ✓ Round t
digit for
decimal
calculatir
(Wong, 2
- ✓ Frame yc
your aud
offer re
(Dando,
- ✓ Use colo
convey
decoratio
Similarly

Don'ts

- × Do not manipulate data to t
story it does not actually tell.
(2001, pp. 55-77) calls
"graphical integrity".
- × Do not use 3D or a "
apart" effect – this reduces
comprehension and makes it hard
to compare elements (Few, 2012,





11. LEGEND

Will a legend be used and if so, where will it go, what size will it be, and what markers will be used? It is not labeled on this image, but the Urban style guide includes a separate section that specifies font sizes for other elements of graphs, including the legend.

12. DATA MARKERS

Will graphs, especially line graphs, include data markers, like circles or squares? Will the markers be filled or hollow? When will data values be labeled? You may want to set rules about using data markers for graphs with some number of values.

13. DATA LABELS

Determine when data points should be labeled and how they should be placed and formatted. The Urban guide has a separate table of font sizes that describes how these labels should appear.

Principle #4 Colors *Always* Mean Something

nale and female

s for each skill/strategy; "viz" is visualization.

ıalization of Delphi Panel 3 results for creating skills/strategies

ormation being conveyed and noise is anything else. The most ef
e signal-to-noise ratio by minimizing visual clutter that might inte
this argument is that one should justify every single pixel in the v

Tips: do's and don'ts for data visualization

Do's:

✓ Pass the squint test: Is the information conveyed without reading any text? Does the right color pop out? Are the labels clear? Try printing out your visualization

Don'ts

× Do not manipulate data to t
story it does not actually tell.
(2001, pp. 55-77) calls
"graphical integrity".
× Do not use 3D or a "
apart" effect – this reduces
comprehension and makes it hard
to compare elements (Few, 2012,

Principle #4 Colors *Always* Mean Something

Purpose
Aesthe
Design clear and e
Highlight relationshi
Facilitating co
Think about research
Color highlight

What are the 3 C's of data visualization?

If you're going to make the most of data visualization, an essential step is to avoid the drawbacks highlighted above. Follow the three C's of data visualization to clearly and accurately present your data.

Clarity

Be clear about the message you're conveying with your visualization. What does the data mean? How does it provide value to the audience? Eye-catching graphs may be good to look at, but they're of no use to stakeholders unless they present important information.

Consistency

It's easy to misread and misinterpret information when there's no consistency in your visualization. The same rules and visual styles should apply across the board.

If you're using one color to represent something in one bar chart, the meaning should be similar across other graphs and charts. For example, if green represents an increase in sales in one chart, it should represent a decline in negative sentiment in another chart.

Context

On its own, data can only tell you so much. It doesn't tell you if a number is good or bad. For example, if your click-through rate is 4.5%, is that a good number? Adding context to your visualization is crucial for a more comprehensive understanding of the data.

ensus
Consensus
No consensus

The 3 Cs for Better Charts

The 3 Cs are an easy way to remember the most important aspects c

- Context
- Clutter-free
- Contrast

✓
✓
✓
✓

(Dando,
✓ Round t
digit for
decimal
calculatir
(Wong, 2
✓ Frame yc
your aud
offer re
(Dando,
✓ Use colo
convey
decoratio
Similarly

12. DATA MARKERS

Will graphs, especially line graphs, include data markers, like circles or squares? Will t
markers be filled or hollow? When will data values be labeled? You may want to set ru
about using data markers for graphs with some number of values.

13. DATA LABELS

Determine when data points should be labeled and how they should be placed and for-
matted. The Urban guide has a separate table of font sizes that describes how these labels
should appear.

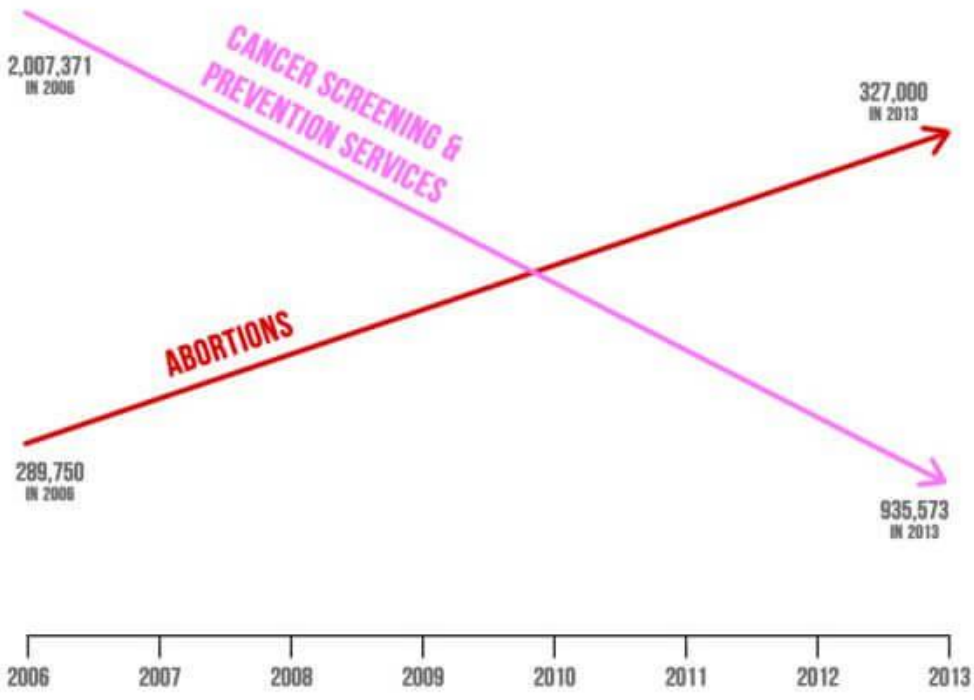
alization of Delphi Panel 3 results for creating skills/strategies

ormation being conveyed and noise is anything else. The most ef
e signal-to-noise ratio by minimizing visual clutter that might inte
this argument is that one should justify every single pixel in the v

Why should we care?

PLANNED PARENTHOOD FEDERATION OF AMERICA:

ABORTIONS UP – LIFE-SAVING PROCEDURES DOWN



SOURCE: AMERICANS UNITED FOR LIFE

Original

Fit as a butcher's dog

Characteristics of dogs registered with the UK's Kennel Club, average when fully grown

Sources: Kennel Club; *The Economist*

*Where at least 50 are registered per year †Where at least 100 are registered per year

Better

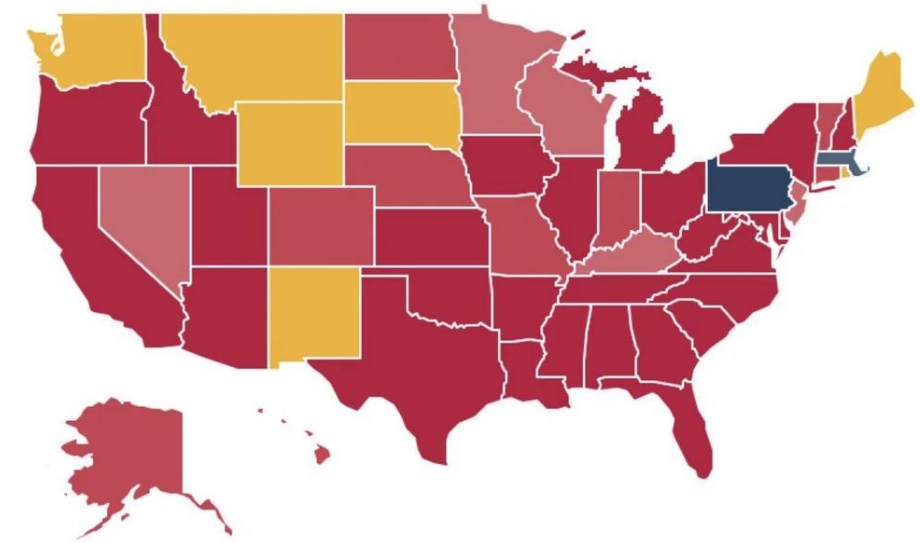
Fit as a butcher's dog

Characteristics of dogs registered with the UK's Kennel Club, average when fully grown

Sources: Kennel Club; *The Economist*

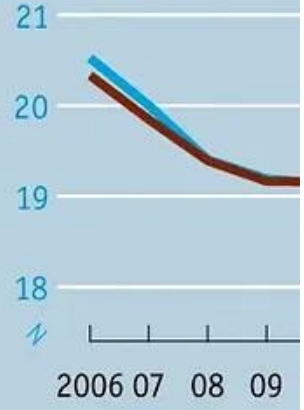
*Where at least 100 are registered per year †Where at least 50 are registered per year

Where cursive writing is taught in the US



Fit as a butcher

Characteristics of do
Kennel Club, average



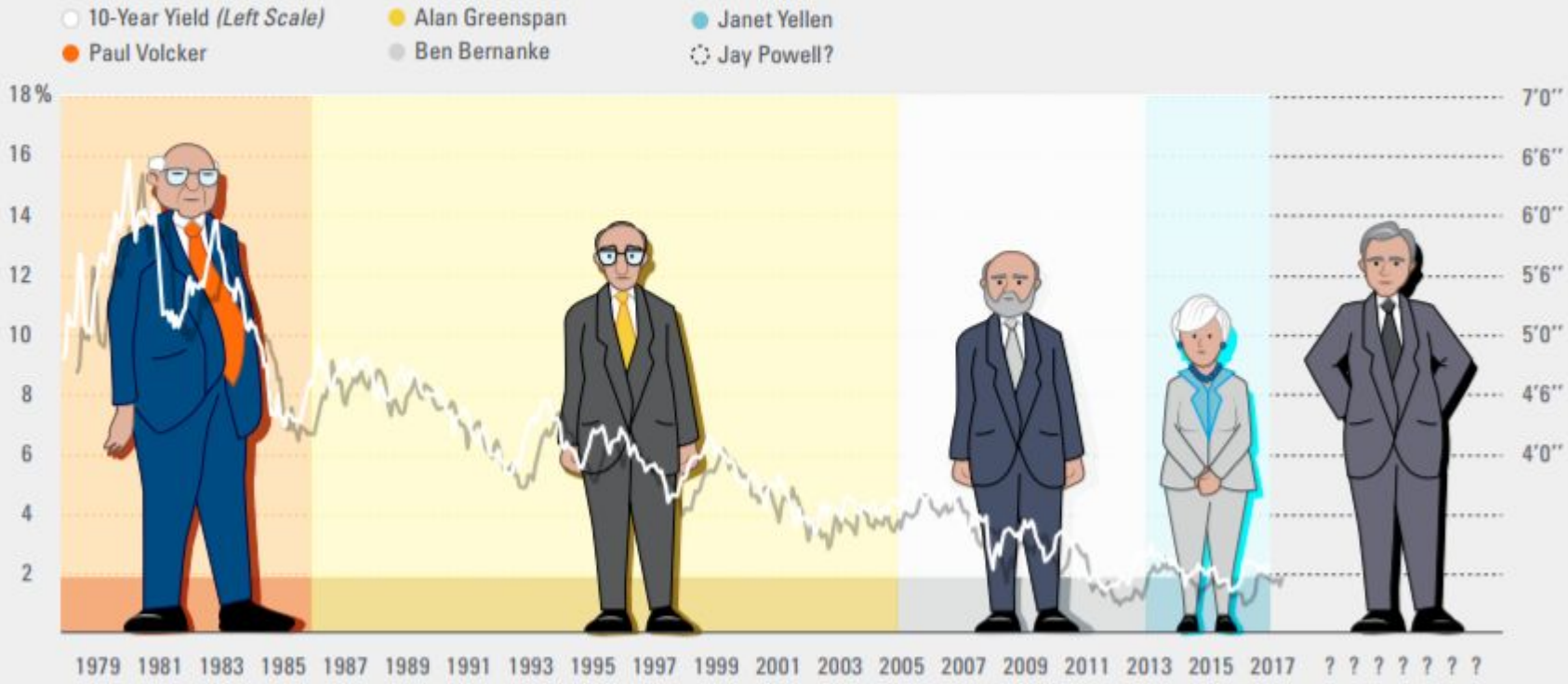
Sources: Kennel Club;
The Economist

log

egistered with the UK's
hen fully grown

at least 100 are registered per year
at least 50 are registered per year

2 BOTH THE HEIGHT OF THE FED CHAIR AND RATES HAVE FALLEN OVER TIME, COULD A TALLER FED CHAIR MEAN RATES RISE?



Source: LPL Research, Bloomberg 10/22/17

We don't actually believe that interest rates are determined by the height of the Fed chair, but it has been an interesting coincidence.

Our Favorite Drugs

The war on drugs keeps law enforcement busy—13 percent of all arrests made in 2007 were drug related—but the kinds of battles police are fighting vary widely across the country, from meth labs in California to cocaine dealers in Florida. This is a look at what drugs local law enforcement officials said were posing the greatest dangers to their communities, when asked by the Department of Justice.

W E S T

WEST/ISLANDS	NORTH/MIDWEST	MIDWEST	SOUTHWEST	SOUTHEAST	FLORIDA/ISLANDS	MID-ATLANTIC	NORTHEAST	NEW ENGLAND
ALASKA, AMERICAN SAMOA, CENTRAL CALIFORNIA, GUAM, HAWAII, IDAHO, NEVADA, NORTHERN CALIFORNIA, NORTHERN MARIANA ISLANDS, OREGON, WASHINGTON	COLORADO, IOWA, KANSAS, MISSOURI, MONTANA, NEBRASKA, NORTH DAKOTA, SOUTH DAKOTA, SOUTHERN ILLINOIS, UTAH, WYOMING	INDIANA, KENTUCKY, MICHIGAN, MINNESOTA, NORTHERN ILLINOIS, OHIO, WISCONSIN	ARIZONA, NEW MEXICO, OKLAHOMA, SOUTHERN CALIFORNIA, TEXAS	ALABAMA, ARKANSAS, GEORGIA, LOUISIANA, MISSISSIPPI, NORTH CAROLINA SOUTH CAROLINA, TENNESSEE	FLORIDA, PUERTO RICO, THE U.S. VIRGIN ISLANDS	DELAWARE, MARYLAND, PENNSYLVANIA, VIRGINIA, WASHINGTON, D.C., WEST VIRGINIA	NEW JERSEY, NEW YORK	CONNECTICUT, MAINE, MASSACHUSETTS, NEW HAMPSHIRE, RHODE ISLAND, VERMONT

E A S T

- PHARMACEUTICALS
- MARIJUANA
- METHAMPHETAMINE
- HEROIN
- COCAINE

7'0"
6'6"
6'0"
5'6"
5'0"
4'6"
4'0"

SOURCE: Department of Justice

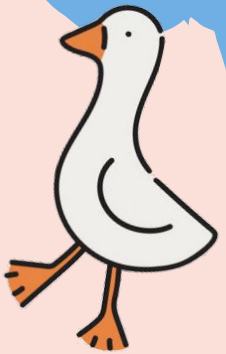
Do you know where your taxes go in the City of Millbrae?

We have broken down Sales Tax and Property Tax so that you know where your tax dollars are going.

Chart 1

My ~loosey goosey~ plan

(input and suggestions greatly appreciated)



01 Collect recommendations/guidelines/advice for the creation of data visualization

02 Identify individual recommendations within each
(and how these are justified: are they evidence-based?)

03 Map recommendations to visual cognitive processes

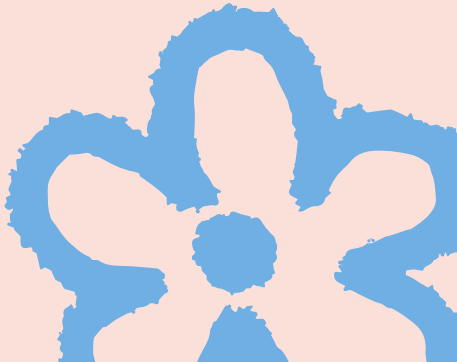
04 Bring computation into the mix
(this is the loosiest goosiest step)

05 Do this on a larger scale

03

End Goal:

A framework built around consumption



Consumption of Data Visualization

Warning:
VERY much a work in progress

(References on final slide)

Consumption of Data Visualization

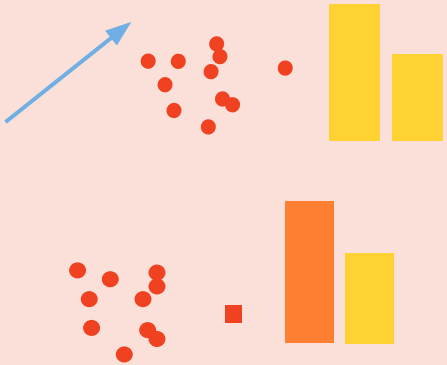
Visual Perception

(References on final slide)

Consumption of Data Visualization

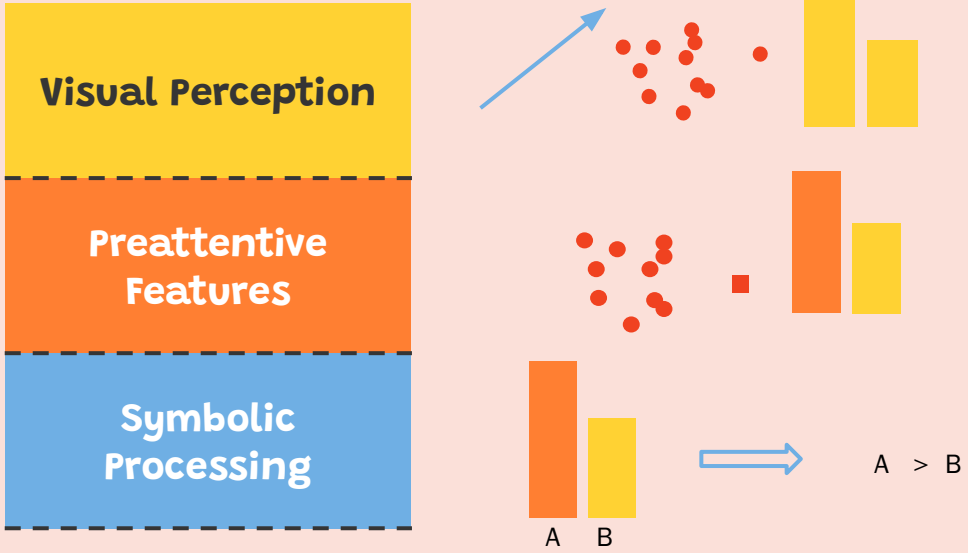
Visual Perception

Preattentive Features



(References on final slide)

Consumption of Data Visualization



(References on final slide)

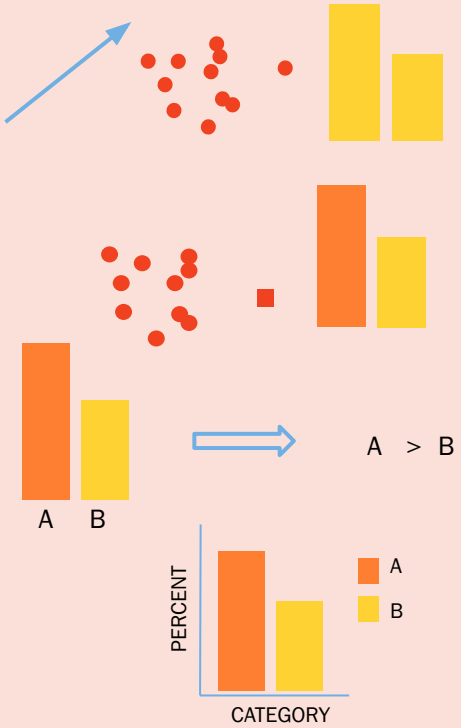
Consumption of Data Visualization

Visual Perception

Preattentive Features

Symbolic Processing

Feature Integration



(References on final slide)

Consumption of Data Visualization

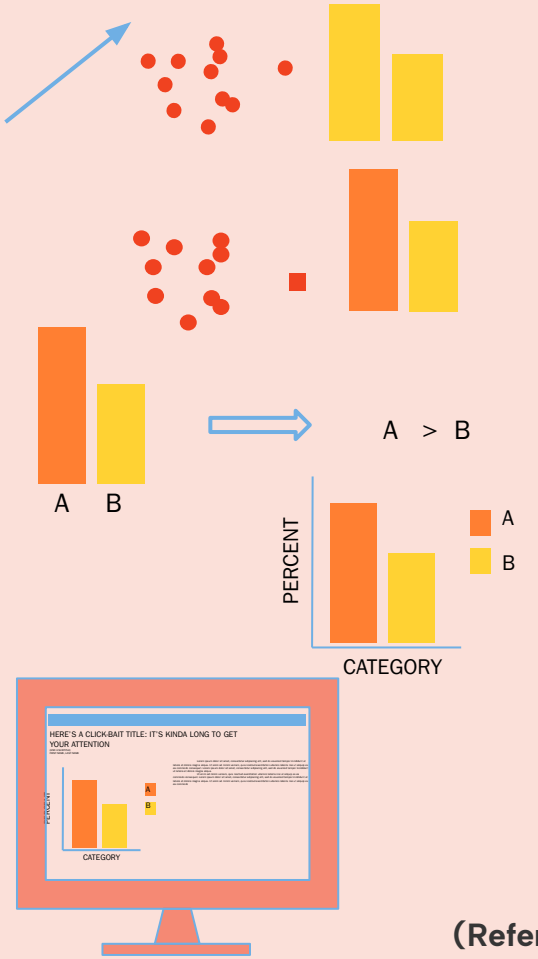
Visual Perception

Preattentive Features

Symbolic Processing

Feature Integration

Contextualization



(References on final slide)

Questions?

Thank You!

CREDITS: This presentation template was created by **Slidesgo**, and includes icons by **Flaticon**, infographics & images by **Freepik** and content by **Sandra Medina**

References

Anouncia, S. M., Gohel, H. A., & Vairamuthu, S. (Eds.). (2020). *Data Visualization: Trends and Challenges Toward Multidisciplinary Perception*. Springer Singapore. https://doi.org/10.1007/978-981-15-2282-6

Archambault, S. G., Helouvry, J., Strohl, B., & Williams, G. (2015). Data visualization as a communication tool. *Library Hi Tech News*, *32*(2), 1–9. https://doi.org/10.1108/LHTN-10-2014-0098

Azzam, T., Evergreen, S., Germuth, A. A., & Kistler, S. J. (2013). Data Visualization and Evaluation. *New Directions for Evaluation*, *2013*(139), 7–32. https://doi.org/10.1002/ev.20065

Bolch, C., & Crippen, K. (2022). DATA SCIENTISTS' EPISTEMIC THINKING FOR CREATING AND INTERPRETING VISUALIZATIONS. *STATISTICS EDUCATION RESEARCH JOURNAL*, *21*(2), 11. https://doi.org/10.52041/serj.v21i2.21

Franconeri, S. L., Padilla, L. M., Shah, P., Zacks, J. M., & Hullman, J. (2021). The Science of Visual Data Communication: What Works. *Psychological Science in the Public Interest*, *22*(3), 110–161. https://doi.org/10.1177/15291006211051956

Grootswagers, T., Robinson, A. K., Shatek, S. M., & Carlson, T. A. (2024). Mapping the dynamics of visual feature coding: Insights into perception and integration. *PLOS Computational Biology*, *20*(1), e1011760. https://doi.org/10.1371/journal.pcbi.1011760

Hehman, E., & Xie, S. Y. (2021). Doing Better Data Visualization. *Advances in Methods and Practices in Psychological Science*, *4*(4), 251524592110453. https://doi.org/10.1177/25152459211045334

Hommel, B., Pösse, B., & Waszak, F. (2000). Contextualization in Perception and Action. *Psychologica Belgica*, *40*(4), 227. https://doi.org/10.5334/pb.964

Kaiser, D., Inciuraite, G., & Cichy, R. M. (2020). Rapid contextualization of fragmented scene information in the human visual system. *NeuroImage*, *219*, 117045. https://doi.org/10.1016/j.neuroimage.2020.117045

Lee, S., Kim, S.-H., Hung, Y.-H., Lam, H., Kang, Y.-A., & Yi, J. S. (2016). How do People Make Sense of Unfamiliar Visualizations?: A Grounded Model of Novice's Information Visualization Sensemaking. *IEEE Transactions on Visualization and Computer Graphics*, *22*(1), 499–508. https://doi.org/10.1109/TVCG.2015.2467195

Midway, S. R. (2020). Principles of Effective Data Visualization. *Patterns*, *1*(9), 100141. https://doi.org/10.1016/j.patter.2020.100141

O'Halloran, K. L. (2015). Mathematics as multimodal semiosis. In *Mathematics, Substance and Surmise: Views on the Meaning and Ontology of Mathematics* (pp. 287–303). Springer.

Osinska, V. (2018). *Visualizing the scientific information nowadays: The problems and challenges*.

Palermos, S. O. (2014). Knowledge and cognitive integration. *Synthese*, *191*(8), 1931–1951. https://doi.org/10.1007/s11229-013-0383-0

Park, J. (n.d.). *THE ROLE OF NUMERICAL COGNITIVE PROCESSES FOR BAR GRAPH COMPREHENSION*. https://hdl.handle.net/11299/257082

Presmeg, N., Radford, L., Roth, W.-M., & Kadunz, G. (2016). *Semiotics in Mathematics Education*. Springer International Publishing. https://doi.org/10.1007/978-3-319-31370-2

Prinzmetal, W. (1981). Principles of feature integration in visual perception. *Perception & Psychophysics*, *30*(4), 330–340. https://doi.org/10.3758/BF03206147

Schnotz, W., & Kulhavy, R. W. (Eds.). (1994). *Comprehension of graphics*. North-Holland.

Schultz, H. D. (2018). Visualizing data in research articles. *The Journal of Physiology*, *596*(16), 3431–3432. https://doi.org/10.1113/JP276501

Schwabish, J. A. (2021). *Better data visualizations: A guide for scholars, researchers, and wonks*. Columbia University Press.

Shah, P. (n.d.). *A Model of the Cognitive and Perceptual Processes in Graphical Display Comprehension*.

Tacca, M. C. (2011). Commonalities between Perception and Cognition. *Frontiers in Psychology*, *2*. https://doi.org/10.3389/fpsyg.2011.00358

Treisman, A. (1985). Preattentive processing in vision. *Computer Vision, Graphics, and Image Processing*, *31*(2), 156–177. https://doi.org/10.1016/S0734-189X(85)80004-9

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*(1), 97–136. https://doi.org/10.1016/0010-0285(80)90005-5

Wade, N., & Swanston, M. (2013). *Visual Perception* (0 ed.). Psychology Press. https://doi.org/10.4324/9780203082263

Ware, C. (2004). Information Visualization: Perception for Design: Second Edition. In *Information Visualization: Perception for Design: Second Edition*.

Wolfe, J. M., & Utochkin, I. S. (2019). What is a preattentive feature? *Current Opinion in Psychology*, *29*, 19–26. https://doi.org/10.1016/j.copsyc.2018.11.005

Yalçin, M. A., Elmqvist, N., & Bederson, B. B. (2016). Cognitive Stages in Visual Data Exploration. *Proceedings of the Sixth Workshop on Beyond Time and Errors on Novel Evaluation Methods for Visualization*, 86–95. https://doi.org/10.1145/2993901.2993902

Zachary, W., Rosoff, A., Miller, L., & Read, S. (2013). Context as a Cognitive Process: An Integrative Framework for Supporting Decision Making. *STIDS Proceedings*.