by

Denise Renee Bradford

## A DISSERTATION

Presented to the Faculty of

The Graduate College at the University of Nebraska In Partial Fulfillment of Requirements

For the Degree of Doctor of Philosophy

Major: Statistics

Under the Supervision of Susan R. VanderPlas, Ph.D

Lincoln, Nebraska Month, Year

Denise Renee Bradford, Ph.D. University of Nebraska, Year

Adviser: Susan R. VanderPlas, Ph.D

Here is my abstract. *(350 word limit)*

© Year, Denise Renee Bradford

## DEDICATION

Dedicated to…

## ACKNOWLEDGMENTS

Thank you to all my people!

**Table of Contents**

|  |  |
| --- | --- |
| [**List of Figures**](#_bookmark0)  [**List of Tables**](#_bookmark1) | **vii**  **viii** |
| [**1 UNL thesis fields**](#_bookmark2) | **1** |
| [**2 Introduction**](#_bookmark3) | **2** |
| [2.1 Perceptual and Cognitive Process of Graph Perception](#_bookmark4) . . . . | 2 |
| [2.2 Data Considerations](#_bookmark5) . . . . . . . . . . . . . . . . . . . . . . . | 2 |
| [2.3 Audience-Data Interactions](#_bookmark6) . . . . . . . . . . . . . . . . . . . | 3 |
| [2.4 Dashboard Design](#_bookmark7) . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| [2.5 Dissertation Map](#_bookmark8) . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| [2.6 Conclusion](#_bookmark9) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 3 |
| [**3 Chapter Paper on Rural Shrink Smart Manuscript submit-**](#_bookmark10)[**ted to Journal of Data Science Special Issue**](#_bookmark10) | **4** |
| [3.1 Abstract](#_bookmark11) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 4 |
| [3.2 Introduction](#_bookmark12) . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 4 |
| [3.3 Data Description](#_bookmark13) . . . . . . . . . . . . . . . . . . . . . . . . . | 4 |
| [3.4 Dashboard Design Considerations](#_bookmark14) . . . . . . . . . . . . . . . . | 4 |
| [3.5 Guiding Design Principles](#_bookmark15) . . . . . . . . . . . . . . . . . . . . | 4 |

* 1. [Dashboard Design Process](#_bookmark16) . . . . . . . . . . . . . . . . . . . . 4
  2. [Discussion](#_bookmark17) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5
  3. [Future Work](#_bookmark18) . . . . . . . . . . . . . . . . . . . . . . . . . . . 5
  4. [Conclusions](#_bookmark19) . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5

1. [The Dashboard as a Unified Chart: Enhancing Data Visu-](#_bookmark20) [alization and Insights](#_bookmark20) 6
   1. [Abstract:](#_bookmark21) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 6
   2. [Introduction:](#_bookmark22) . . . . . . . . . . . . . . . . . . . . . . . . . . . 6
   3. [Related Work:](#_bookmark23) . . . . . . . . . . . . . . . . . . . . . . . . . . . 7
   4. [Unified Chart Dashboard Design:](#_bookmark24) . . . . . . . . . . . . . . . . 8
   5. [Experimential Ideas/Methods to test theory:](#_bookmark25) 10
2. [Tables, Graphics, References, and Labels](#_bookmark26) 12
   1. [Dashboard EDA](#_bookmark27) 12

[Conclusion](#_bookmark28) 13

[A The First Appendix](#_bookmark29) 14

[B The Second Appendix, for Fun](#_bookmark30) 15

[Colophon](#_bookmark31) 16

[References](#_bookmark32) 20

**List of Figures**

**List of Tables**

**Chapter 1**

**UNL thesis fields**

Placeholder

# Chapter 2

**Introduction**

Placeholder

# Perceptual and Cognitive Process of Graph Percep- tion

* + 1. **Visual System**
    2. **Gestalt Principles**
    3. **Role of Attention and F.I.T. (Feature Integration Theory)**
    4. **Top-Down vs. Bottom-Up (Construting Meaning)**
    5. **Working Memory (Why can’t I remember someone’s phone number?)**
    6. **Role of Expertise**
    7. **Engagement with the data**

# Data Considerations

**2.2.0.1 Interactive Graphics**

# Audience-Data Interactions

* + 1. **Human-Computer Interaction (HCI)**
    2. **User Experience (UX)**
    3. **UX and Cognitive Load**
    4. **Infomation Search Enviroment**
    5. **Chart Coordination/Viusal Linking**
    6. **Testing static graphics**
    7. **Testing interactive graphics**
  1. **Dashboard Design**
  2. **Dissertation Map**
  3. **Conclusion**

**Chapter 3**

**Chapter Paper on Rural Shrink Smart Manuscript submitted to Journal of Data Science Special Issue**

Placeholder

* 1. **Abstract**
  2. **Introduction**
  3. **Data Description**
  4. **Dashboard Design Considerations**
  5. **Guiding Design Principles**

# Dashboard Design Process

* + 1. **Dashboard Components**
    2. **Initial Draft**
    3. **Redesign**

# Discussion

# Future Work

# Conclusions

**Chapter 4**

**The Dashboard as a Unified Chart: Enhancing Data Visualization and Insights**

# Abstract:

This write-up explores the concept of considering an entire dashboard as a unified chart in data visualization. Traditionally, dashboards are composed of multiple charts representing various aspects of data. However, this study proposes a novel approach where the entire dashboard is treated as a single chart, leveraging its interactive and interconnected elements to enhance data visualization and insights.

# Introduction:

The grammar of graphics is a framework for designing and comprehending data visualizations. By decomposing graphics into components such as data, aesthetics, and geometries, the grammar of graphics provides a structured method for conceiving and creating visualizations. It permits a high degree of customization and flexibility in the creation of visualizations. The principles of the grammar of graphics can be applied to dashboard design to create more

effective and informative dashboards.

# Related Work:

* + 1. **Dashboard Design**

The process of creating visually informative and interactive interfaces that present data and key performance indicators (KPIs) in a consolidated and simple-to-understand format is dashboard design. The objective is to provide users with insights and enable them to make intelligent decisions based on the presented data.

* + 1. **Grammar of Graphics**

The central concept of the grammar of graphics is the representation of visualizations as a combination of essential components, including data, aes- thetics, geometries, scales, and statistics. These components can be combined in numerous ways to generate a vast array of visual representations. For in- stance, data is the foundational element, aesthetics map data variables to vi- sual properties, geometries determine the representation of data points, scales map data values to visual values, and statistics transform the data prior to visualization.

While the grammar of graphics provides a powerful theoretical framework for data visualization, there may be research gaps in its application to dash- board design and functionality. Such as the following missing pieces:

**Interactivity and User Experience:** Graphics grammar primarily em- phasizes static visualizations. However, dashboards are inherently interactive, allowing users to explore the data and interact with it. There is a need for

research to determine how to effectively incorporate the principles of the gram- mar of graphics into interactive dashboards while maintaining a positive user experience and avoiding user overload.

**Dashboard Composition:** The grammar of graphics emphasizes the creation of individual visualizations. Yet, dashboards involve combining mul- tiple visualizations into a single interface. Research is needed to explore best practices for composing different charts and graphs in a dashboard to ensure coherent storytelling and effective data communication.

**Data Synchronization:** Dashboards often present data from multiple sources or datasets. Ensuring data synchronization across different visualiza- tions and components is critical to maintain accuracy and consistency. Re- search is needed to investigate methods for handling data updates, refresh rates, and synchronization challenges in dashboard design.

**User-Centered Design:** The grammar of graphics focuses on data- driven principles, but effective dashboard design also requires a deep under- standing of user needs, tasks, and goals. Further research should investigate how to integrate user-centered design practices into the application of the grammar of graphics in dashboard development.

# Unified Chart Dashboard Design:

Here is how published theory relates graphic grammar to dashboard design:

**Data Layer:** Data is the foundation of visualizations in the grammar of graphics. This means that data should drive the dashboard design pro- cess. Dashboards should be constructed using accurate, pertinent, and well-

organized data that aligns with the dashboard’s objectives.

**Aesthetics Layer:** refer to the mapping of data variables to visual prop- erties such as color, size, shape, and position. Aesthetics play a crucial role in dashboard design for accurately and effectively representing data. Choos- ing appropriate colors, scales, and shapes for visual elements expedites users’ ability to comprehend and interpret data.

**Geometries:** determine how data points, such as bars, lines, points, or areas, are represented in the visualization. The selection of appropriate geome- tries is crucial in dashboard design for communicating the intended message. Various types of charts and graphs may be used to represent various types of data or to illustrate particular relationships.

**Composition and Layers:** The grammar of graphics permits the com- bination of multiple layers of data and geometries to generate more complex visualizations. This translates to structuring information hierarchically in dashboard design, utilizing multiple charts, graphs, or elements to present a comprehensive view of the data without overwhelming the user.

**Faceting:** is the process of dividing data into subsets and displaying them as multiple smaller visualizations. Faceting can be used in dashboard design to display multiple aspects of the data simultaneously, making it easier for users to compare and contrast various parts of the data.

**Annotations:** As mentioned in the previous response, annotations are a crucial component of statistical graphics and also apply to dashboard design. Annotations strategically placed can aid users in comprehending key insights, provide context, and guide them through the dashboard’s narrative.

Using the principles of the grammar of graphics, designers can create vi- sually appealing, informative, and user-friendly dashboards that effectively convey data-driven insights to their audience.

# Experimential Ideas/Methods to test theory:

Testing the effectiveness of a dashboard as a unified chart involves eval- uating its usability, user experience, and the effectiveness of conveying infor- mation to the target audience. Here are some key steps and methods to test the effectiveness of a dashboard with a unified chart:

**Usability Testing:** Conduct usability testing with real users to observe how they interact with the dashboard. Use think-aloud protocols, where users vocalize their thoughts while using the dashboard. Observe if users can easily navigate, interpret data, and find relevant information using the unified chart.

**A/B Testing:** Implement A/B testing by creating different versions of the dashboard. Present one group of users with the unified chart version and the other group with a non-unified chart version. Compare user performance and feedback between the two groups to determine the impact of the unified chart.

**Eye-Tracking:** Use eye-tracking technology to understand where users focus their attention on the dashboard. This will reveal if users are drawn to the critical information presented through the unified chart.

**User Interviews and Observations:** Conduct interviews with users to gain deeper insights into their experiences and preferences regarding the unified chart. Observe how users interact with the dashboard in their natural

environment.

**Chapter 5**

**Tables, Graphics, References, and Labels**

# Dashboard EDA

# Conclusion

If we don’t want Conclusion to have a chapter number next to it, we can add the {-} attribute.

**More info**

And here’s some other random info: the first paragraph after a chapter title or section head *shouldn’t be* indented, because indents are to tell the reader that you’re starting a new paragraph. Since that’s obvious after a chapter or section title, proper typesetting doesn’t add an indent there.

# Appendix A

**The First Appendix**

This first appendix includes all of the R chunks of code that were hidden throughout the document (using the include = FALSE chunk tag) to help with readibility and/or setup.

**In the main Rmd file**

library(knitr)

**In Chapter** [**5**](#_bookmark26)**:**

**Appendix B**

**The Second Appendix, for Fun**

# Colophon

This document is set in [EB Garamond](https://github.com/georgd/EB-Garamond), [Source Code Pro](https://github.com/adobe-fonts/source-code-pro/) and [Lato](http://www.latofonts.com/lato-free-fonts/). The body text is set at 11pt with *lmr*.

It was written in R Markdown and *L*A*T*E*X*, and rendered into PDF using [huskydown](https://github.com/benmarwick/huskydown) and [bookdown](https://github.com/rstudio/bookdown).

This document was typeset using the XeTeX typesetting system, and the [University of Washington Thesis class](http://staff.washington.edu/fox/tex/) class created by Jim Fox. Under the hood, the [University of Washington Thesis LaTeX template](https://github.com/UWIT-IAM/UWThesis) is used to ensure that documents conform precisely to submission standards. Other elements of the document formatting source code have been taken from the [Latex, Knitr,](https://github.com/stevenpollack/ucbthesis) [and RMarkdown templates for UC Berkeley’s graduate thesis](https://github.com/stevenpollack/ucbthesis), and [Dissertate:](https://github.com/suchow/Dissertate) [a LaTeX dissertation template to support the production and typesetting of](https://github.com/suchow/Dissertate) [a PhD dissertation at Harvard, Princeton, and NYU](https://github.com/suchow/Dissertate)

The source files for this thesis, along with all the data files, have been organised into an R package, xxx, which is available at [https://github.](https://github.com/xxx/xxx) [com/xxx/xxx](https://github.com/xxx/xxx). A hard copy of the thesis can be found in the University of Washington library.

This version of the thesis was generated on 2023-07-20 15:24:43. The repository is currently at this commit:

The computational environment that was used to generate this version is as follows:

## - Session info ## setting value

## version R version 4.2.2 (2022-10-31) ## os macOS Big Sur ... 10.16

## system x86\_64, darwin17.0 ## ui X11

## language (EN)

## collate en\_US.UTF-8 ## ctype en\_US.UTF-8

## tz America/New\_York

## date 2023-07-20

## pandoc 2.19.2 @ /Applications/RStudio.app/Contents/Resources/app/quarto/bin/tools/ ##

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ##  ## | - Packages  package | \* version | date (UTC) | lib | source |  |
| ## | bookdown | 0.33 | 2023-03-06 | [1] | CRAN (R | 4.2.0) |
| ## | cachem | 1.0.7 | 2023-02-24 | [1] | CRAN (R | 4.2.0) |
| ## | callr | 3.7.3 | 2022-11-02 | [1] | CRAN (R | 4.2.0) |
| ## | cli | 3.6.1 | 2023-03-23 | [1] | CRAN (R | 4.2.0) |
| ## | crayon | 1.5.2 | 2022-09-29 | [1] | CRAN (R | 4.2.0) |
| ## | devtools | 2.4.5 | 2022-10-11 | [1] | CRAN (R | 4.2.0) |
| ## | digest | 0.6.31 | 2022-12-11 | [1] | CRAN (R | 4.2.0) |
| ## | ellipsis | 0.3.2 | 2021-04-29 | [1] | CRAN (R | 4.2.0) |
| ## | evaluate | 0.21 | 2023-05-05 | [1] | CRAN (R | 4.2.0) |
| ## | fastmap | 1.1.1 | 2023-02-24 | [1] | CRAN (R | 4.2.0) |
| ## | fs | 1.6.2 | 2023-04-25 | [1] | CRAN (R | 4.2.0) |
| ## | glue | 1.6.2 | 2022-02-24 | [1] | CRAN (R | 4.2.0) |
| ## | htmltools | 0.5.4 | 2022-12-07 | [1] | CRAN (R | 4.2.0) |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ## | htmlwidgets |  | 1.6.2 | 2023-03-17 | [1] | CRAN | (R | 4.2.0) |
| ## | httpuv |  | 1.6.9 | 2023-02-14 | [1] | CRAN | (R | 4.2.0) |
| ## | knitr | \* | 1.42 | 2023-01-25 | [1] | CRAN | (R | 4.2.0) |
| ## | later |  | 1.3.0 | 2021-08-18 | [1] | CRAN | (R | 4.2.0) |
| ## | lifecycle |  | 1.0.3 | 2022-10-07 | [1] | CRAN | (R | 4.2.0) |
| ## | magrittr |  | 2.0.3 | 2022-03-30 | [1] | CRAN | (R | 4.2.0) |
| ## | memoise |  | 2.0.1 | 2021-11-26 | [1] | CRAN | (R | 4.2.0) |
| ## | mime |  | 0.12 | 2021-09-28 | [1] | CRAN | (R | 4.2.0) |
| ## | miniUI |  | 0.1.1.1 | 2018-05-18 | [1] | CRAN | (R | 4.2.0) |
| ## | pkgbuild |  | 1.4.0 | 2022-11-27 | [1] | CRAN | (R | 4.2.0) |
| ## | pkgload |  | 1.3.2 | 2022-11-16 | [1] | CRAN | (R | 4.2.0) |
| ## | prettyunits |  | 1.1.1 | 2020-01-24 | [1] | CRAN | (R | 4.2.0) |
| ## | processx |  | 3.8.1 | 2023-04-18 | [1] | CRAN | (R | 4.2.0) |
| ## | profvis |  | 0.3.7 | 2020-11-02 | [1] | CRAN | (R | 4.2.0) |
| ## | promises |  | 1.2.0.1 | 2021-02-11 | [1] | CRAN | (R | 4.2.0) |
| ## | ps |  | 1.7.5 | 2023-04-18 | [1] | CRAN | (R | 4.2.0) |
| ## | purrr |  | 1.0.1 | 2023-01-10 | [1] | CRAN | (R | 4.2.0) |
| ## | R6 |  | 2.5.1 | 2021-08-19 | [1] | CRAN | (R | 4.2.0) |
| ## | Rcpp |  | 1.0.10 | 2023-01-22 | [1] | CRAN | (R | 4.2.0) |
| ## | remotes |  | 2.4.2 | 2021-11-30 | [1] | CRAN | (R | 4.2.0) |
| ## | rlang |  | 1.1.1 | 2023-04-28 | [1] | CRAN | (R | 4.2.0) |
| ## | rmarkdown |  | 2.20 | 2023-01-19 | [1] | CRAN | (R | 4.2.2) |
| ## | rstudioapi |  | 0.14 | 2022-08-22 | [1] | CRAN | (R | 4.2.0) |
| ## | sessioninfo |  | 1.2.2 | 2021-12-06 | [1] | CRAN | (R | 4.2.0) |
| ## | shiny |  | 1.7.4 | 2022-12-15 | [1] | CRAN | (R | 4.2.0) |
| ## | stringi |  | 1.7.12 | 2023-01-11 | [1] | CRAN | (R | 4.2.0) |
| ## | stringr |  | 1.5.0 | 2022-12-02 | [1] | CRAN | (R | 4.2.0) |
| ## | urlchecker |  | 1.0.1 | 2021-11-30 | [1] | CRAN | (R | 4.2.0) |
| ## | usethis |  | 2.1.6 | 2022-05-25 | [1] | CRAN | (R | 4.2.0) |
| ## | vctrs |  | 0.6.2 | 2023-04-19 | [1] | CRAN | (R | 4.2.0) |
| ## | xfun |  | 0.37 | 2023-01-31 | [1] | CRAN | (R | 4.2.0) |

|  |  |  |  |
| --- | --- | --- | --- |
| ## | xtable | 1.8-4 | 2019-04-21 [1] CRAN (R 4.2.0) |
| ## | yaml | 2.3.7 | 2023-01-23 [1] CRAN (R 4.2.0) |
| ## |  |  |  |

## [1] /Library/Frameworks/R.framework/Versions/4.2/Resources/library ##

##

# References

Placeholder