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# Placing Graphic Design at the Intersection of Information Visualization Fields

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## Abstract

The popularity of information visualization in academia and practice brings a renewed emphasis on aesthetic values and visual applications to ensure its appeal to a wider audience. This paper focuses on visualization aesthetics and perception by making the case for using graphic design techniques and design languages to understand and create more aesthetically pleasant and functionally effective information design and visualization. It uses cross-disciplinary reviews of background research to demonstrate the value of graphic design principles and methods in the realm of visualization education. A user-centered design framework and student projects are discussed by adapting graphic design elements into the visualization process. It shows that the practice of developing a visualization should be executed with an understanding of graphic design basics in mind, and with a balanced consideration of tangible and conditional design elements, as well as how these design elements fulfill the purpose of the objective, context, content, audience, and the knowledge of the design outcomes.

## Introduction

Information Visualization is defined as a set of technologies that use visual computing to amplify human cognition with abstract information. The purpose of visualization is to communicate complex ideas with clarity, precision, and efficiency to encourage objective analysis [Card et al. 1999]. Early research and applications of Information Visualization (infoVis) mostly originated from computer science, cartography, and statistics; the teaching focus was mainly for students fluent in computer systems and technology with the goal of creating innovative visualization tools [Bertin 1983] [Cleveland 1993] [Tufte 1997]. In recent years, many humanities scholars, artists, designers, and news media outlets have exploited innovative visualization to deliver data-oriented content. These efforts made visualization more accessible to the public, and created more demand for information design and infoVis classes from the education system. The popularity of infoVis also brings a renewed emphasis on aesthetic values and visual applications to ensure its appeal to a wider audience. 1

In a recent collaborative class focusing on data visualization projects between Computational Data Visualization students and Visual Communication Design students of the Ohio State University, 36.7% of students ranked the quality of communication between the two disciplines as less than or equal to 3 on a scale of 1 to 5 (1 being “impossible” and 5 being “nice and easy”) in a post-class survey. As expressed in student comments, some reasons behind the communication gap come from different problem-solving processes and the overall learning goals of each discipline. Some are originated from the different perspective on visual literacy education. However, there are strong connections between modern graphic design and computational visualization in many aspects. The shared goal of visualization and graphic design practices is the desire to pursue objectivity, rationality, and clarity. Visualization as taught in science and engineering disciplines is considered purely analytical and intellectual, but people’s response to visual images are also visceral and emotional. Images made from data, as in Computational Data Visualization courses, are no exception. 2

More and more infoVis-related projects take a synthesis approach that involves multi-disciplinary teams of experts, so being able to understand each other and integrate knowledge and methods from different disciplines can also facilitate 3 the collaboration process and make the connections among the various sub-fields clear to students. Therefore, infoVis researchers and practitioners also need to be educated about the impact of choices in design elements and styles – which are usually taught in the field of art and design.

This paper focuses on visualization aesthetics and perception by making the case for using graphic design techniques and design languages to understand and create more aesthetically pleasant and functionally effective information design and visualization. Viewpoints from different academic methodologies can often benefit the development of one discipline, especially a field like infoViz that has its roots in a variety of areas. In order to formulate a modularity-based design approach, first the infoVis design process will be introduced to understand the context of *Visualizing*. Then the foundation of aesthetics of both fields – infoVis and graphic design — will be discussed, as well as the visual parameters included in the two fields. How graphic design elements can be adapted into the visualization process will be presented through a user–centered framework and student projects. In this way, researchers and practitioners who come from a variety of disciplines can understand and communicate to their students how graphic design is a thread that runs through all aspects of infoVis. 4

## The Process of Information Visualization

The process of infoVis, like all creative design processes, is an iterative cyclic system. The cycle that involves defining, research, analyzing, ideating, visualizing, and evaluation are iterative, but also flexible and interconnected (Figure 1). The stage of *Visualizing* includes a constant interplay between *visual queries* and *visual encoding*. In his book *Visual Thinking for Design*, Colin Ware defined *visual queries* as the acts of attention involved in visual thinking, which are "driving eye movements and tuning our pattern-finding circuits" [Ware 2008]. *Visual encoding* is the mapping of information to visually display elements [Muzner 2015]. Skilled designers will visually encode the data to support the visual queries, and different encoding strategies will also alter the results of visual queries. 5

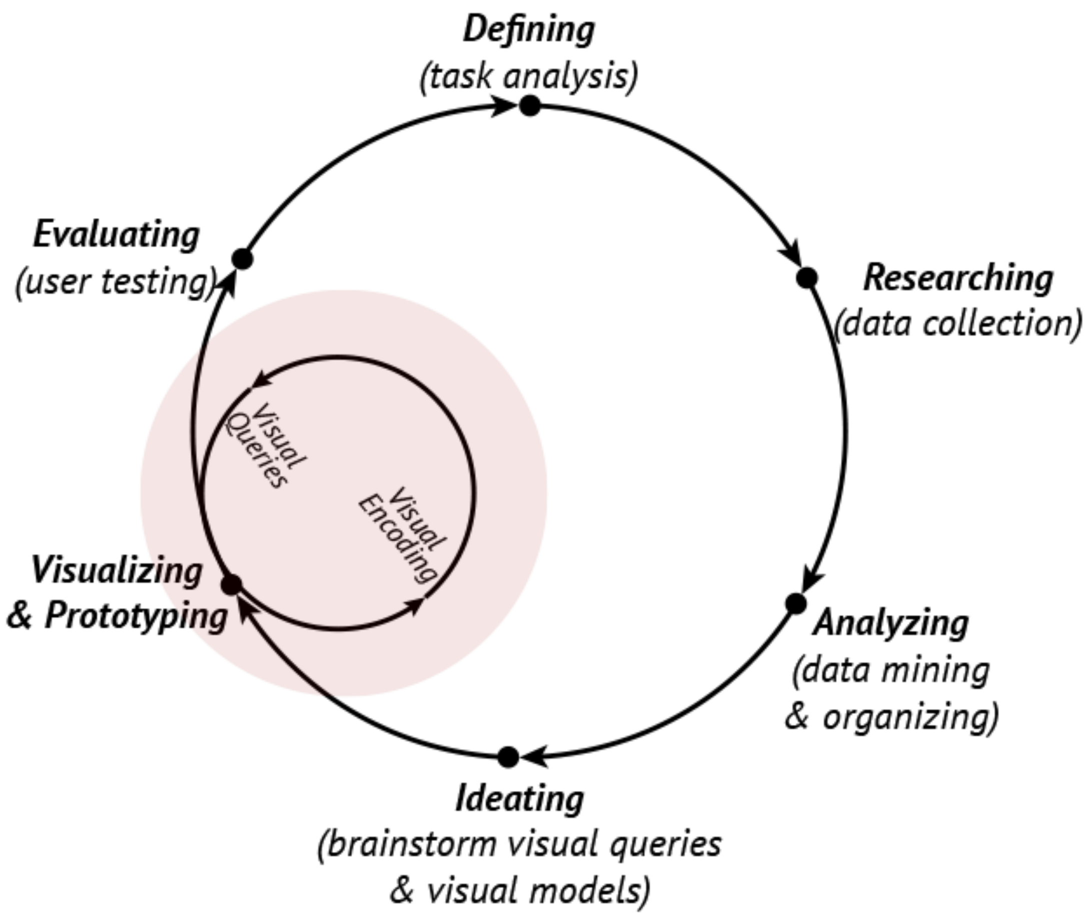


**Figure 1.** Information Visualization Design Process

## Aesthetics of Graphic Design and InfoVis

The visual encoding tools and strategies that have been heavily researched by scientists and engineers are largely focused on solving functional requirements, for example, how visual encoding technologies relate to multidimensional databases or how they are applied to a particular programming language or software [Bostock et al. 2011] [Stolte et al. 2002]. But less attention has been paid to the aesthetics or the visual appeals of the information being presented. In recent years, there have been more efforts spent on visualization methods that are both visually appealing as well as technically efficient. For example, popular visualization tools such as Tableau and RAWGraphs (Figures 2 and 3) both adopt modern design aesthetics that support better user experience and user engagement. This is one way in which the field of graphic design unifies the multi-faceted infoVis discipline.

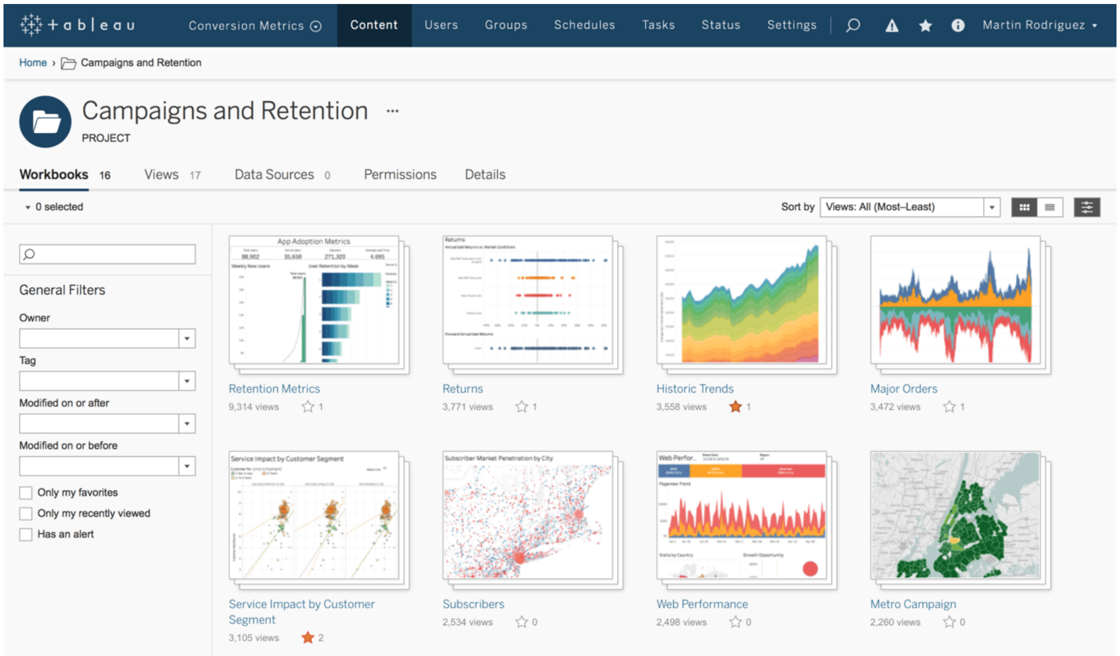


**Figure 2.** Tableau and RAWGraphs (Figure 3) both adopt clean and crisp aesthetics in the visualization tools that the software provides. Image source: https://www.tableau.com/products/server

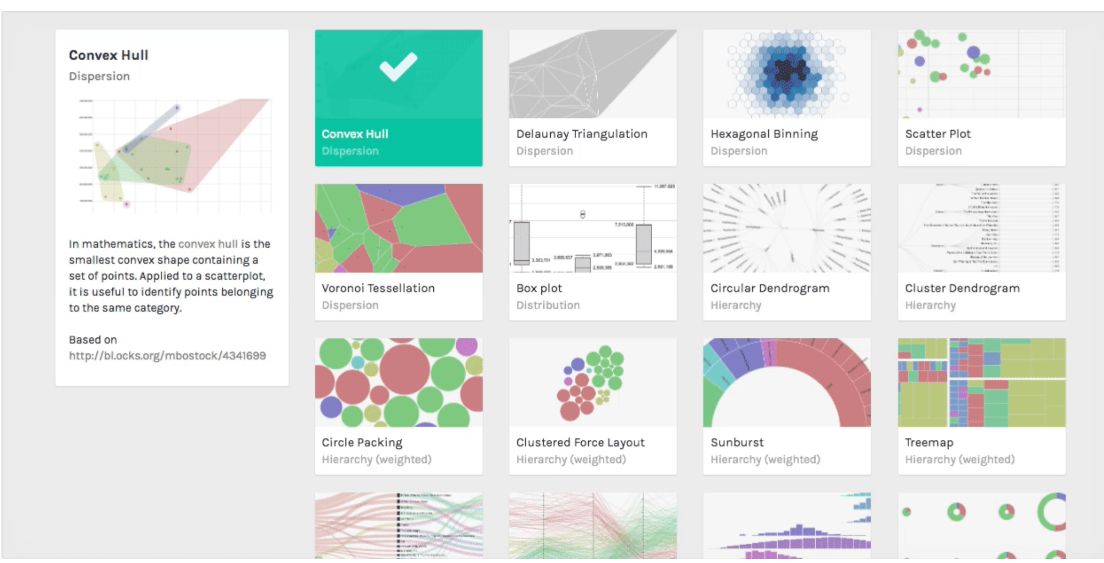


**Figure 3.** Tableau (Figure 2) and RAWGraphs both adopt clean and crisp aesthetics in the visualization tools that the software provides. Image source: https://rawgraphs.io/new-release/raw-graphs-updates-with-version-1-2-0/

The modern graphic design aesthetics, shaped by the Bauhaus School (1919-1933) and the International Typographic Style (1950s), imply geometric layout, orderly typography, effective use of white space, and simple color composition, foster universal forms, and aim to objectify representations of cultural diversity by making them appear economical and perceptually transparent [Kostelnick 2004]. Edward Tufte, who is arguably the most influential theoretician in information design and visualization, also stressed the importance of “minimal and efficient” design [Cairo 2013]. Tufte advocates the functionalism of information graphics: “Data graphics should draw the viewer’s attention to the sense and substance of the data, not to something else” [Tufte 2004, 91]. His notion of visual aesthetics rigidly follows minimalism and anti-ornamentation for clear and elegant display. As the field of infoVis has experienced a burst of popularity and growth to include various scientific and computation-focused disciplines in recent years, graphic design’s involvement must be reemphasized in regard to visualization content, perception, and aesthetics. 7

Graphic designers’ efforts to find the perfect balance in aesthetic and functional design principles are compatible with the cognition-based approach of visualization scientists. In scientific fields, infoVis is considered as cognitive tools in problem solving, so the focus is on visual perception, visual attention, and the pattern of information processing. Similarly, the effectiveness and efficiency of content delivery was advocated by modern graphic designers who championed functional and universal visual language. Graphic design’s visual language can be layered onto the pattern of information processing to ensure visual appeal through essential visual elements such as form, layout, typography, and use of color. 8

## Visual Parameters in Science and Design

Visualization researchers such as Bertin, Cleveland, Ware, and Munzner identified visual parameters as the foundation to generate well-known visualization techniques. Visual parameters refer to the set of visual options that are used to construct design solutions that meet a specific product requirement. This visual encoding process known by the visualization scientists has a deep connection with the foundational design education across art and design schools around the world. The visual principles and attributes that contribute to the parameters are either aligned with or responding to the design ideologies rooted in Gestalt psychology and the Bauhaus school. One of the Bauhaus masters Wassily Kandinsky exploited the design curriculum of studying forms and understanding colors using psychology and perception (Wassily Kandinsky - Wikipedia, 2018). However, regardless the shared knowledge base, there still are communication gaps between visualization *scientists* and visualization *designers*. 9

The visual education for scientists starts from analyzing data semantics and types. Then they encode data with marks and channels. Munzner defines graphical elements as marks, and visual channels are ways to control marks’ appearances [Muzner 2015]. Design students’ education starts from learning points, lines, planes, and composition tactics. In the book *Exploring the Elements of Design*, the authors identified two groups of design elements - tangible and conditional [Evans et al. 2013]s. The tangible elements concern physical forms; and the conditional elements are the ones only exist if the tangible element is established. Visual designers’ work process pays more attention to achieving the best visual quality by actively constructing different visual parameters [Cross 2007]. The comparisons of visual parameters included in Visualization (science) and Graphic Design (design) are shown in Table1. The overlapping elements demonstrate the similarities of visual constructions from the two approaches. 10

| **Visualization (science)** (Munzner, 2015) | | **Graphic Design (design)** (Evans & Thomas, 2013) | |
|---|---|---|---|
| Visual Marks | Visual Channels | Design Elements (tangible) | Design Elements (conditional) |
| Points | *Size* | Space | *Size* |
| *Lines* | *Color* | *Line* | *Color* |
| Areas | Position | Texture | Value |
| | *Shape* | *Shape* | Volume |
| | Tilt | Type | |

**Table 1.** The visual parameter comparisons in science and design with shared parameters italicized.

The shared or similar visual parameters, however, may be considered for different functions and purposes between science and design. For example, the line mark in science visualization is commonly seen as an element that can formulate quantitative value through variation in size or position such as a bar chart or line graph. But from the graphic design perspective, line is an element that can be used to separate or divide information as well as to show connections and links. It can indicate boundary or point out directions. Different styles of lines also inherit various characteristics. Thin lines suggest delicacy and convey a tranquil and elegant quality; and thick lines are often associated with emphasis and strength (Figure 4). Gesture lines may also be used to represent form and movement (Figure 5). 11

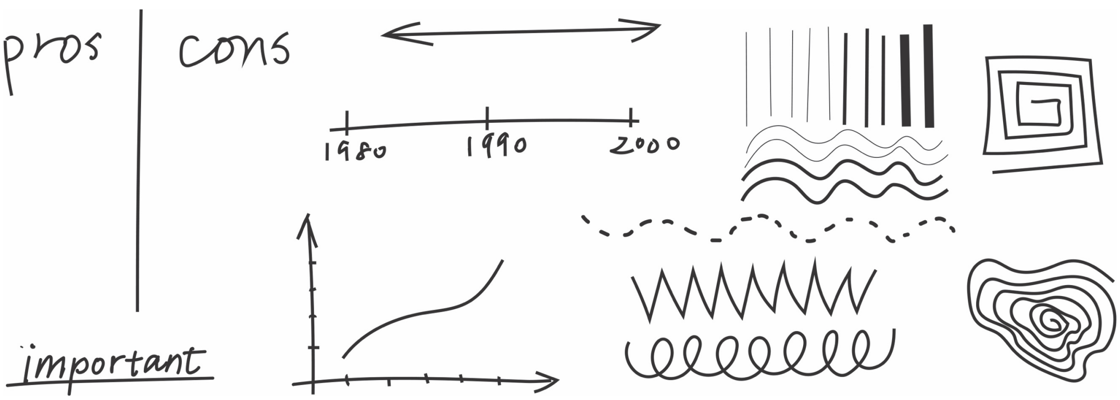


**Figure 4.** Different types and functions of lines

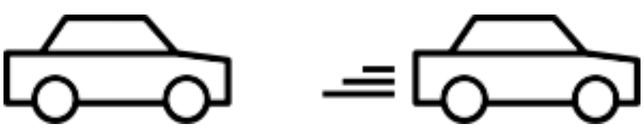

**Figure 5.** The visual focus shifts to motion rather than the object itself by adding gesture lines

## Design Elements in InfoVis Create a User-Centered Framework

InfoVis is a broad and exploratory discipline that requires a galaxy of disparate tactics bind together to create functional and visually-engaging solutions. Therefore, infoVis designers should not only know the practical meanings of the visual parameters defined in the science field, but also understand how the language of visual design can improve the aesthetic and functional quality. The relationships between the concepts of form, function, and content may be obvious to those with design training backgrounds, but less to the science and humanities community who also create infoVis frequently in their fields [Vande Moere and Purchase 2011]. 12

In addition to aesthetic and usability concerns, the design considerations are also crucial in identifying and framing the goals of the visualization. Figure 6 demonstrates a modularity approach to understand design elements in the context of visualization. Modern design strictly follows a user-centered approach [Norman 2002]. All stages in the visualization 13 process entail design thinking: the choice of data set and attributes, as well as the visual encoding choice to support the visual queries. How the contents are chosen, how the forms are constructed, how the objective of the project is portrayed to the audiences through visual representations, and how the messages can ultimately influence people's knowledge, attitudes, and behavior – the existence and choice of the design elements always affect and are affected by these concerns. The connection between these variables forms a dialogical approach that results in a framework of the semantic components (right side) to be expressed through a particular set of syntactic components (left side). Modifications of one side influence the outcomes of the other. Different methods of organizing and expression can create different perspectives and influence how the information is perceived. Each individual component has its own purpose, yet they all rely on each other to function as a unit.

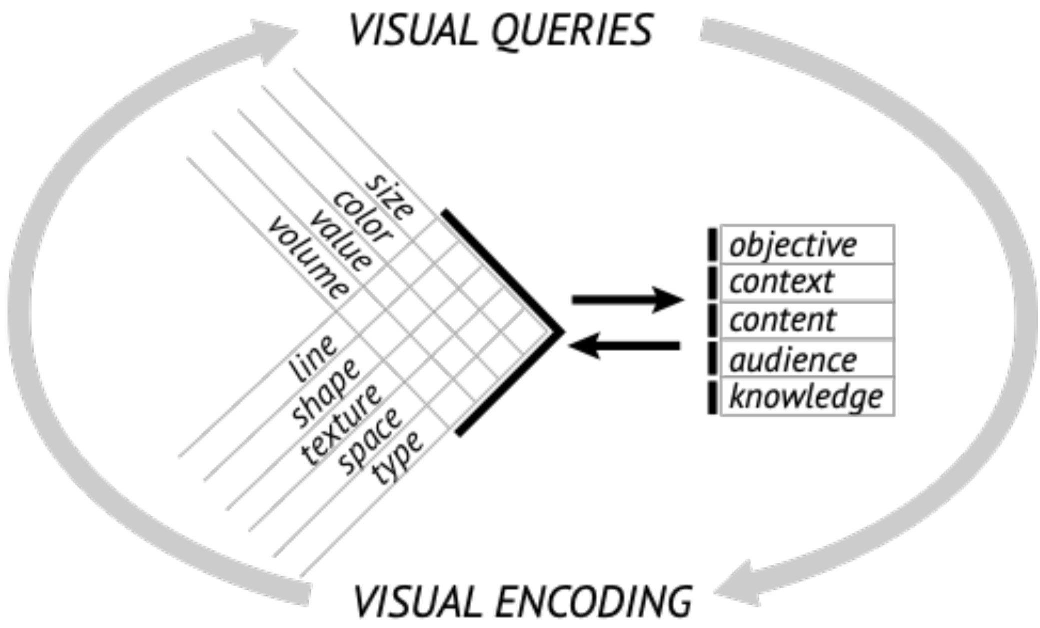


**Figure 6.** A modularity approach to demonstrate how design concerns are addressed in the context of visualization

To better understand the correlations between the two sets of modules, the next section will study some student project examples that demonstrate how design elements used in information visualization and information design projects help to increase the quality of form and function. The examples reflect where design glossaries are introduced and fed back into the visualization problem in a non-design major information design and visualization course. 14

# Case Studies

## Line and Shape

The student project shown in Figure 7 is based on the data record of Grammy award winners. In this print-based project, lines are used to perform different functions. They are used to separate events on a timeline; the left or right direction separates the male and female artists; and the weight variations (the strength, heaviness, or darkness of a line) indicate different types of artists (a thin line indicates an individual artist and a thick line indicates a group or a band). Changing weights pushes the lines closer and further apart, they create rhythms and dynamism in the composition. The lines and their intervals also create the illusions of spatial depth that helps viewers have a quick grasp of the gender distributions of Grammy winners through history. The line element being considered from a graphic design perspective is able to bring more meanings and visual dynamics to an otherwise unimaginative regular timeline approach. 15

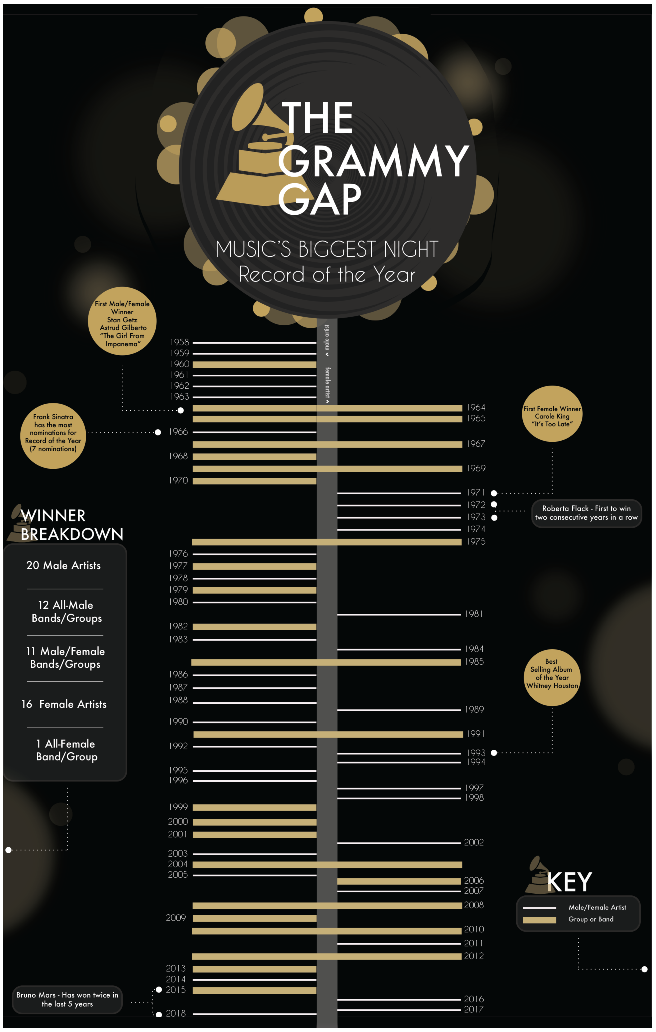


**Figure 7.** "The Grammy Gap" information visualization poster by Emma Duncliffe (New Media & Communication Technology major)

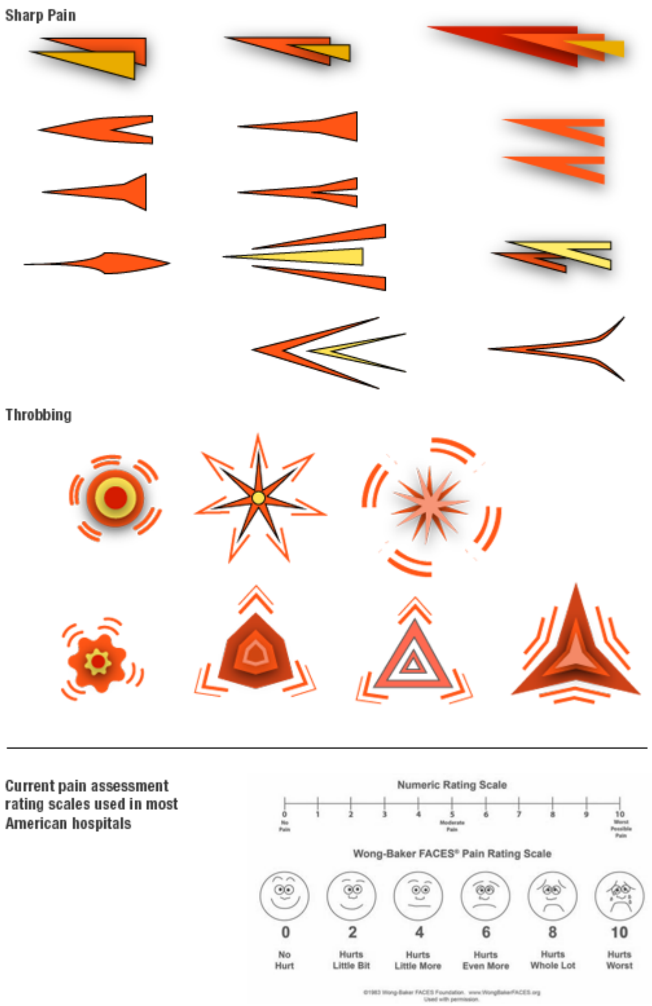


**Figure 8.** "Visualizing Pain" — using shapes to represent pain in contrast to the current pain rating tools used in most American hospitals (image source: https://whyy.org/segments/reassessing-the-assessment-of-pain-how-the-numeric-scale-became-so-popular-in-health-care/). Pain assessment tool research study by Sana Behnam (Design Research and Development)

16 When lines meet to form an enclosed area, it becomes a shape. Every shape, no matter how abstract it appears, carries meanings. Even the three primary geometric shapes — circle, square, and triangle — convey different messages to the audiences. The roundness and the continuity of a circle translate completion and harmony. The equal straight lines and perfect right angles make a square seem stable and formal. The sharp angles and points in triangle embody active and aggressive sensations. The choice of shape is critical if it is to communicate the right message to the audience. Figure 8 shows a portion of a visual pain study based on research conducted for a medical pain visualization assessment tool. Student used abstract shapes to metaphorically represent different type and the intensity of pain. In contrast to the current popular Numeric Rating Scale and the Wong–Baker Faces Pain Rating Scale, different qualities of shapes add more dimensions to the scale of pain measurement. The connotation of symbols is also an attempt to establish better communication with the patients.

## Color, Type, and Space

17 Colors in infoVis can help distinguish different types of information, as well as reinforce the connection between groups of information. Charts and diagrams in information design are often associated with color-coding. Color-coding is the process of attaching a specific color to a category or grouping of content to make it instantly recognizable. In the interactive visualization project shown in Figure 9, different color usage strategies are applied to two similar maps. The design of choropleth maps is based on the scales of value (brightness and darkness of a particular hue) change so that the audience can easily perceive the pattern density. Hue contrast (blue, yellow, green) are then applied to the second

map in order to emphasize the comparisons of the three distinct groups. Graphic designers often rely on color wheels to choose effective and balanced color palette for a visual composition. The value contrast shown in the first map is considered as monochromatic color relationships which include variations of value in one single color. The color choice on the second map shows analogous color relationships which include one color and its neighboring colors on a color wheel (Figure 10). Both color combinations share a common blue hue and all are closely related on a color wheel. This "designerly" way of choosing color ensures varieties of colors to fulfil different purposes, yet still represents a satisfying unity that is pleasing to the eye.

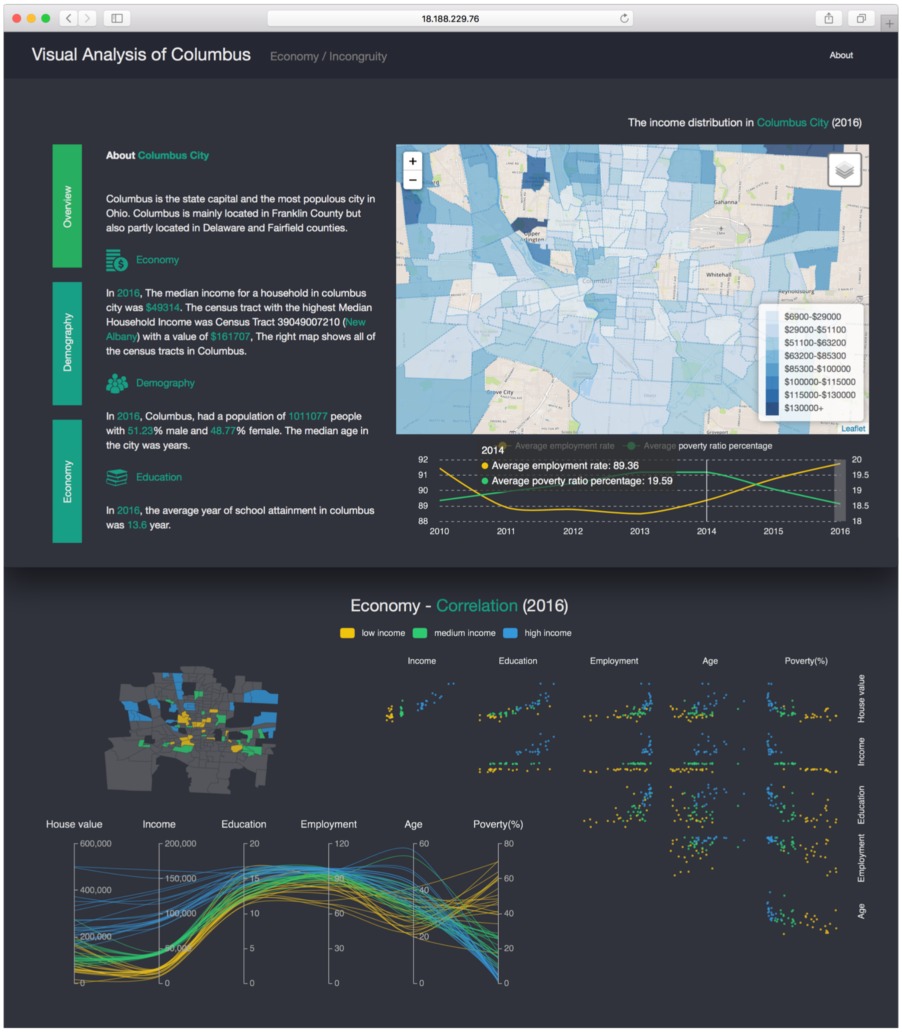


**Figure 9.** Use contrast of value and contrast of hue for different content and objective. "Economic Incongruity in Columbus Ohio" by Rui Li, Zuanxu Gong, Yi Ling, Xiao Yue, Hongliang Shi, Madison Ackerman, and Emily Datsko (collaboration between Computational Data Visualization students and Visual Communication Design students)

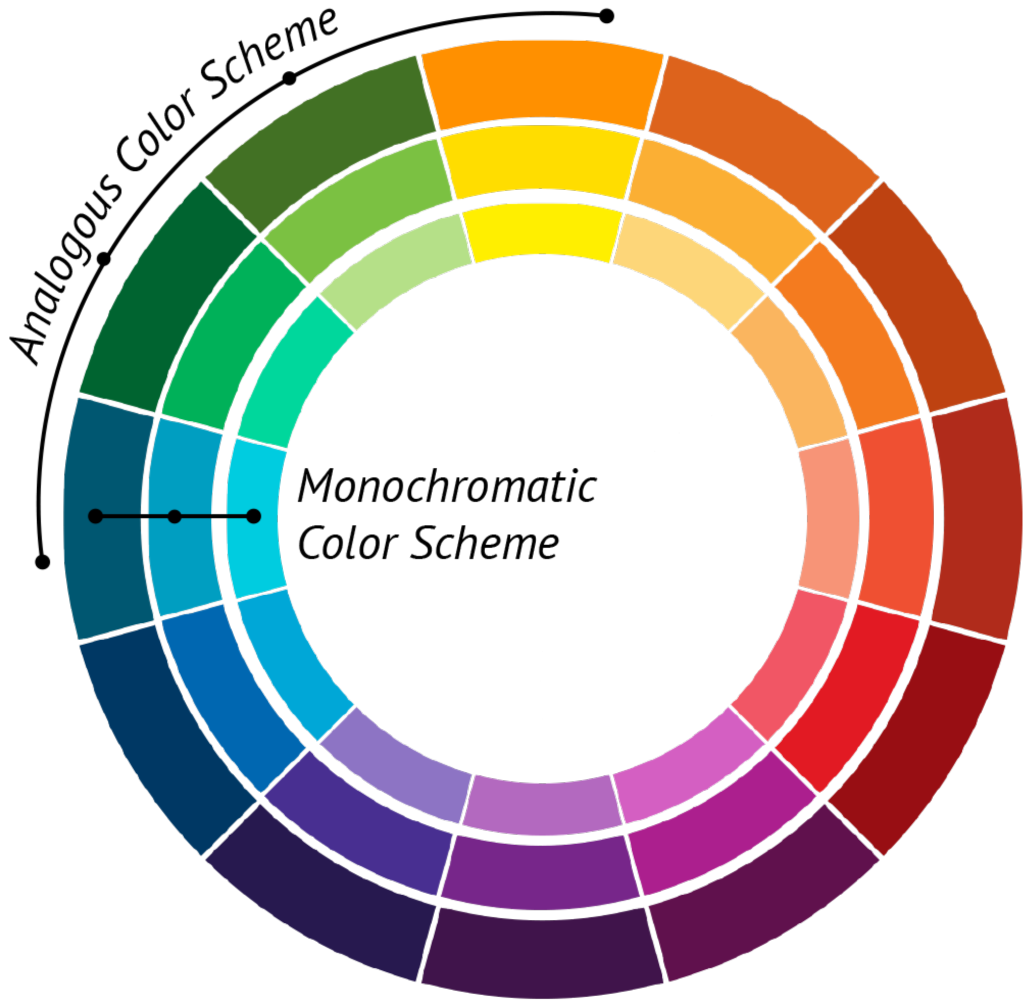


**Figure 10.** Designers use color wheels to choose visually pleasant and balanced color palette. Some combination strategies are time-tested for their visual effectiveness.

Color also inherits psychological connotations that can be used to influence content. Its effect on imagery – both abstract and representational – is of great concern for a given communication. The individual color applied to the object or subject may influence the emotional responses in the viewer. Figure 11 shows a nutrition label redesign exercise that requires students to focus on using and organizing various pieces of visual information. Complementary colors are used to contrast the appearances and significations of the two types of nutrition ingredients. Red color evokes the sense of warning to associate with "negative" ingredients; while green, the color of life, is applied to healthy ingredients. 18

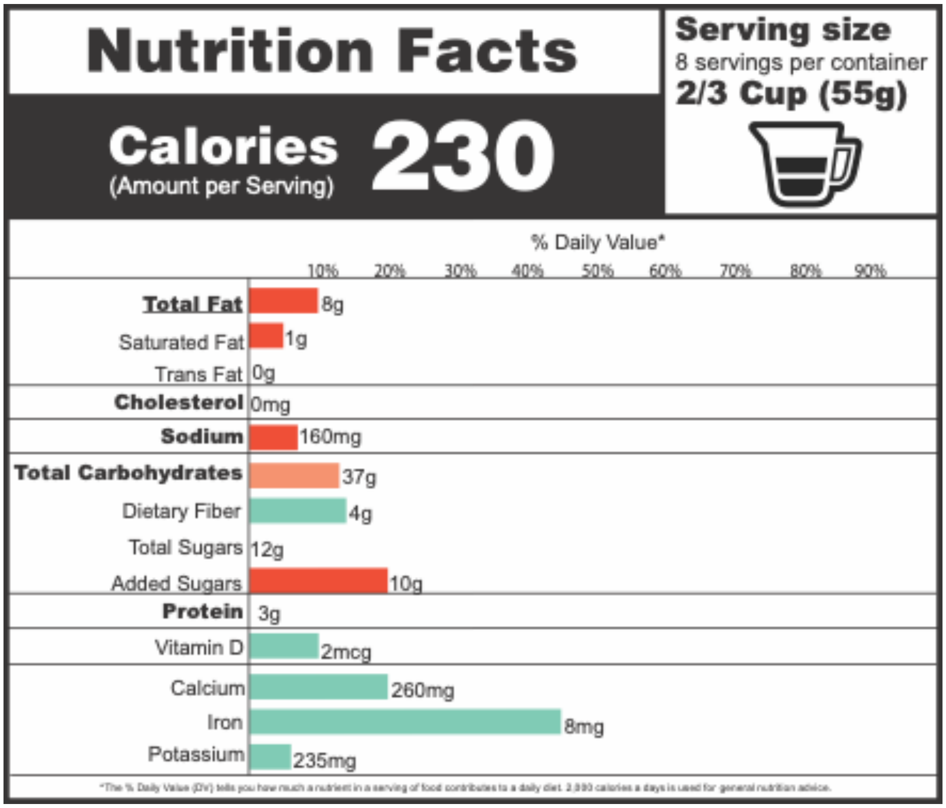


**Figure 11.** The Nutrition label redesign exercise trains students to visually depict quantifiable information while paying attention to type, space, and color relationships. By Sydney Ballish (Integrated Systems Engineering major)

The attention to typography and space are the other design considerations practiced in this exercise. In infoVis the essential typographic concerns are legibility and readability. Legibility refers to perception. It is the ability to clearly distinguish one letter from another within a font. Readability refers to comprehension. It examines how lines and paragraphs of text can be easily read. The spatial relationships between letters, words, and interlines, the length of the text line, the x-height of a letter form and the font style are all important to readability issues [Kunz 2002]. The layers of information in the nutrition label are established through different styles and weight of the type, and how space is structured within or between the visual elements. 19

Over the years, the Gestalt Principles have become invaluable tools for designers to make sure that different visual components within a design composition are well connected and coherent. Originally developed in the field of psychology, Gestalt Principles are a set of laws describing how humans tend to see objects by grouping similar elements, recognizing patterns and simplifying complex images. Some principles are directly related to information organization, such as the law of proximity. It indicates how elements that are close to each other are perceived to be related when compared with elements that are separate from each other. It allows designers to use whitespace, for example, to build perceived relationships between different elements. The label exercise demands students to divide the information into different parts, then practice the Gestalt Principles, and use mainly conditional design elements (see Table 1) to organize content and create hierarchy based on the level of importance among the content. 20

## Conclusion and Discussion

The design projects discussed in the previous section require students to collect and analyze structured or unstructured data and information, and use graphic design principles and techniques to ensure the aesthetic and communication qualities of the visualization. The visual choices made through graphic design methods are all through logical reasoning. This essay uses cross-disciplinary reviews of background research to demonstrate the value of graphic design principles and methods in the realm of visualization education, without which there can be a perceived lack of unifying 21 content across the various courses or disciplines that make up infoVis, especially on the part of students who take those courses. It shows that the practice of developing a visualization should be executed with an understanding of graphic design basics in mind, and with a balanced consideration of tangible and conditional design elements, as well as how these design elements fulfill the purpose of the objective, context, content, audience, and the knowledge of the design outcomes.

Information or Data Visualization education would benefit from looking outside of the traditional science domain, and adopting educational components from the visual design discipline, such as those described in this paper. In addition to understanding the basic design principles, tactics commonly used in graphic design education that can lead to further explorations that fall outside the scope of this essay may include: analyzing best practices, employing design research methods, engaging in peer critiques, involving usability testing and user evaluations, and further expanding the role of infoVis to the content of service design and the trends of design for social good. They will also assist the discussion and justification of the visualization process in cross-disciplinary team practices. 22

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