

**HERE | NOW | LOOK | SEE:
INFORMATION VISUALIZATIONS OF RECENT CLIMATE RECORDS IN ALBERTA**

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Abstract

This thesis is an analysis of the application of information visualization and design to wicked problems, a class of problems whose complexity, interconnectedness and fluctuation make them extremely difficult to resolve, and serves as a supporting document for my studio research and practice. In this paper I identify challenges that emerge with information visualizations of wicked problems and describe methods for addressing these challenges through my practice-based research project. Using climate data provided by Dr. Stefan W. Kienzle, Associate Professor of Hydrology and GIS at the University of Lethbridge, my research project attempts to use information visualization to communicate the climate data by applying design strategies that explore the relationship between aesthetic and functionality.

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Introduction

This paper discusses a project that explores methods for making scientific research accessible and comprehensible to the general public through the design of information visualization. Information visualization uses interactive visual representations of abstract (non-spatial) data to allow viewers to discover patterns, correlations, relationships, and key insights that may not have been apparent otherwise (Ferster, 5). Incorporating computer science, graphic design, cognitive psychology, semiotics, statistical graphing, cartography, and art, information visualization is gaining recognition in both academic and mainstream circles as a powerful form of visual communication. This rapidly growing multi-disciplinary field is becoming increasingly relevant in the current information age, as vast amounts of data are being produced at unprecedented rates through all digital facets. These datasets have enormous potential to reveal new insights about the world and how we live in it, creating a large demand for information visualization to help give the raw data meaning and subsequent value.

Since the discipline was formalized in 1999, research and practice has grown from a primary use of analytical tasks in specialist fields to its application for use by everyday people to provide meaningful insights (Pousman, Stasko, and Mateas, 2007). Artists, programmers, designers, and makers are eagerly taking up the practice of using information visualization to share ideas with the general public that can then become part of the cultural discourse (Tanyoung, 2). In particular, there has been a surge of information visualization projects that aim to increase public knowledge of highly complex issues like poverty, sustainability, and healthcare, which are referred to as *wicked problems*. Known for being extremely resistant to resolution, wicked problems are characterized by the complexity, interconnectedness, and fluctuation of their components, causing indeterminacy and conflicting standpoints on how to resolve them (Buchanan, 15). Given the difficulty of

comprehensively understanding wicked problems due to their complexity, information visualization is becoming a favored approach for its capacity to visually represent complex and abstract data relationships while maintaining intelligibility.

One work that exemplifies the use information visualization to educate the public about a wicked problem is *The Refugee Project* created in 2014 by Hyperakt and Ekene Ijeoma (Fig 1). Based on data provided by the UN, the interactive creates a narrative of refugee migrations since 1975. The interactive allows the user to browse the world map that shows peak migrations between countries shift through the years, in many cases, providing explanations for why displacements occur.

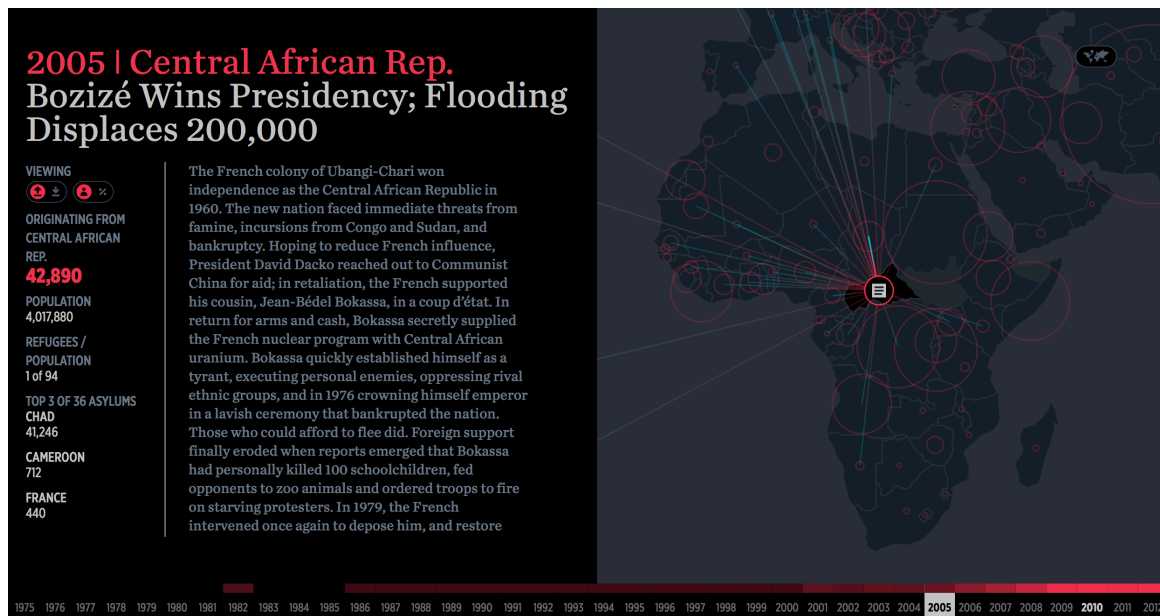


Fig 1: Still from *The Refugee Project* (2014) by Hyperakt and Ekene Ijeoma. Source: therefugeeproject.org

Selected for the MOMA's Design and Violence Exhibition and written about in several publications across the globe, *The Refugee Project* accrued nearly one million page views in its first six months (Hyperakt), a considerable size of audience to be exposed to the issue. However, the effectiveness of the exposure remains a difficult metric to measure; at the MOMA exhibition, an important reflective question is posed to the viewer:

“While the origins of the sentiment are contested, it's true that the death of one person is a tragedy while the death of millions risks becoming a statistic. Does the visualization of big data regarding forced displacement help us comprehend this particular type of violence, or increase our apathy?”

In other words, does the visualization strike a cord with the audience or does the tragedy of the individual refugee get lost in the large numbers? When designing visualizations that deal with wicked problems and involve complex and charged content, like that present in *The Refugee Project*, many challenges emerge, information apathy being just one of them. Of interest to my research are similar challenges that also affect how the audience engages with the visualization. The three challenges this thesis work focuses on and I argue are critical to consider when designing information visualizations of wicked problems are data literacy, information apathy, and bias.

Data Literacy

Data literacy refers to the audience's ability to decode visual representations that can be more difficult to understand as a reflection of the complexity of wicked problems; they come with the potential for larger datasets, more interconnectedness, unfamiliar domain expertise, and many other fluctuating components.

Information Apathy

The abundance of information we are exposed to and the incessant calls-to-action have made many apathetic towards the charged content that can be involved in visualizations of wicked problems, decreasing the effectiveness of communication attempts.

Bias

Both the audience and author engage with any topic through the lens of their pre-existing perceptions. The conflicting standpoints created by many wicked problems can heighten the presence of bias; for the audience, this can hinder the communication of information,

especially if the message contradicts their standpoint; for the author, biases affects how the information is presented and can sometimes lead to misrepresentation.

As one of information visualization's definitive objectives is to amplify cognition, the barriers that data literacy, information apathy, and bias present have the potential to undermine the purpose of any visualization that deals with wicked problems. In response to this challenge, my research and practice explores the question: *In what ways can design methodologies be applied to the practice of information visualization in order to mitigate the challenges of data literacy, information apathy, and bias when communicating information on wicked problems?*

This question is investigated through the project *Here | Now | Look | See: Information Visualizations of Recent Climate Records in Alberta*, which works with sixty years of climate data from 6,834 locations across Alberta provided by Dr. Stefan W. Kienzle, Associate Professor of Hydrology and GIS at the University of Lethbridge. Covering a region where discourse on climate change has become extremely polarized due to competing interests in resource extraction, this dataset provides a promising opportunity to address challenges of disseminating wicked problems through information visualization. Using models and methodologies from design, visual communication, and information visualization, *Here | Now | Look | See* aims to present climate data to the public of Alberta in a way that facilitates deeper comprehension (in response to data literacy), is personally meaningful (in response to information apathy), and is cognizant of biases in the audience and the author (in response to bias).

Project Description

My studio-based practice of designing information visualizations began with finding a collaborative partner. I found that partnership with Dr. Stefan Kienzle, Associate Professor

in the Department of Geography at the University of Lethbridge, who not only provided the data, but also the wicked problem. Access to Dr. Kienzle's climate data allowed me to target my point of inquiry to this very tangible and challenging task: effectively visualizing and communicating this complex dataset to a non-expert public. The data is made up of sixty years of records for twenty-one climate indices (annual day counts of temperature patterns like frost days, days above 25°C, full days below 0°C, etc.), specific to 6,834 10km² grid locations across Alberta.

The project was conceptualized around the unique aspects of the dataset that provided opportunities for me to address data literacy, information apathy, and bias. These aspects include that the data is local to small regions across Alberta, is a recent history, and is challenging due to its size and subject matter of climate change, a topic that remains controversial in Alberta. Along with creating visualizations of the climate data, supplementary visualizations of related data provide additional information and context to create a more comprehensive narrative. The result of this approach is five visualizations, each exploring different design approaches that have resulted in a range of aesthetics and functionalities, titled *Here | Now | Look | See: Information Visualizations of Recent Climate Records in Alberta*. The main narrative in the project is based on breaking down the meaning of each of these keywords (here, now, look, and see) in connection with the climate data. Each stage of the narrative provides information that the audience carries forward to the next, allowing for the totality of information to be complex, but the delivery to be incremental, building comprehension gradually.

The first visualization, *Here: the natural state of Alberta*, speaks to the localization of the data. Based on ecological features of the natural regions and subregions of Alberta, *Here* establishes a foundation of knowledge on the natural composition of Alberta (as it exists

today). My design approach for this piece experiments with methods for providing detailed contextual reference through a non-traditional visualization form.

The second visualization, *Now: an accumulation of the past*, provides context around the sixty year time period of the climate data. By comparing sixty years to other time periods related to human experiences in Alberta, like when the first peoples arrived 14,014 years ago and when Alberta became a province 109 years ago, a unique perspective is formed on how the climate data relates to our notion of time and inhabitation.

The third visualization, *Look: the record of change in Alberta*, invites the audience to look at the climate data itself. The changes in climate trends (explained in depth later on) for each location are visualized through colour encoding across a map of Alberta. The user can quickly see differences in the changes from location to location.

The fourth visualization, *See: effects of a changing climate*, is based on a report that summarizes the effects of climate change in the Prairie Provinces. The visualization is a complex web of causes and effects that result from changing temperature.

Lastly, *Climate Change in Alberta? A Recent History of Climate Trends in Our Backyards*, enables the user to closely study the climate data for each grid location. The details to be discovered are as vast as the dataset. Every data point is made accessible through this interactive.

Terminology

The working definition of information visualization that I use in this paper was presented by three of the discipline's pioneers, Stuart K. Card, Jock D. MacKinlay, and Ben Shneiderman, in 1999. They define the practice as "the use of computer-supported, interactive, visual representations of abstract data to amplify cognition, [which is the acquisition or use of knowledge]" (7). Their inclusion of interactivity differentiates

information visualization from other related fields like information graphics, data visualization, or statistical graphics, which don't specify an interactive component but may still utilize it.

As both information visualization and scientific visualization involve interactivity, Card, MacKinlay and Shneiderman also specify that it is the use of *abstract* data that differentiates information visualization. Abstract data consists of concepts or relationships with no specific physical existence, like the results of a survey, website analytics, vehicle attributes, as opposed to non-abstract data used in scientific visualization which is physically based or has an inherent spatial structure (Oliveira and Levkowitz, 379). While some components of the work produced for this thesis would be defined as scientific visualization due to their use of non-abstract climate data, the series as a whole frames these within visualizations of abstract concepts and relationships to create a more comprehensive and meaningful understanding of the climate data.

Foundations in Information Visualization

A Brief History

The first known use of the term “information visualization” was in 1989 in an article by George G. Robertson, Stuart K. Card, and Jock D. MacKinlay. They used it to describe an application “which uses 2D and 3D animation to explore information and its structure” (10). From this fundamental understanding, it would be another ten years before Card, MacKinlay and Shneiderman present a cohesive framework for the discipline in *Readings in Information Design: using vision to think* (1999). For them, information visualization is a response to the problem of mapping non-spatial data, such as business information, document collections, and abstract conceptions (all referred to as *abstract data*), to an effective visual form¹ (7). By giving data a visual form, we make use of external cognition, which is the ability for people to use an external resource to support thinking rather than having to imagine everything; a powerful way to process information more efficiently (Card, MacKinlay and Shneiderman, 1). Recognizing this, Card, MacKinlay and Shneiderman proposed a model of information visualization focused on amplifying cognition of abstract data through visual representations that are also computer-based and interactive (7). These five essential components; *computer-based, interactive, visual representations, abstract data, and amplify cognition*; created a foundation for research and practice routed in technology, innovation, and the sharing of knowledge.

¹ In contrast, for spatial, non-abstract data that are often used in scientific visualizations, the visualform is more obvious, as data points can be mapped to a representation of their physical location in space (Card, MacKinlay and Shneiderman, 7).

While the current digital interactive form of information visualization has only been in practice for less than two decades, the relationship between scientific observation and graphical representation dates back centuries in the form of graphs and diagrams. One of the oldest known examples is a 10th century time-series graph showing planetary movements over time (Fig 2).

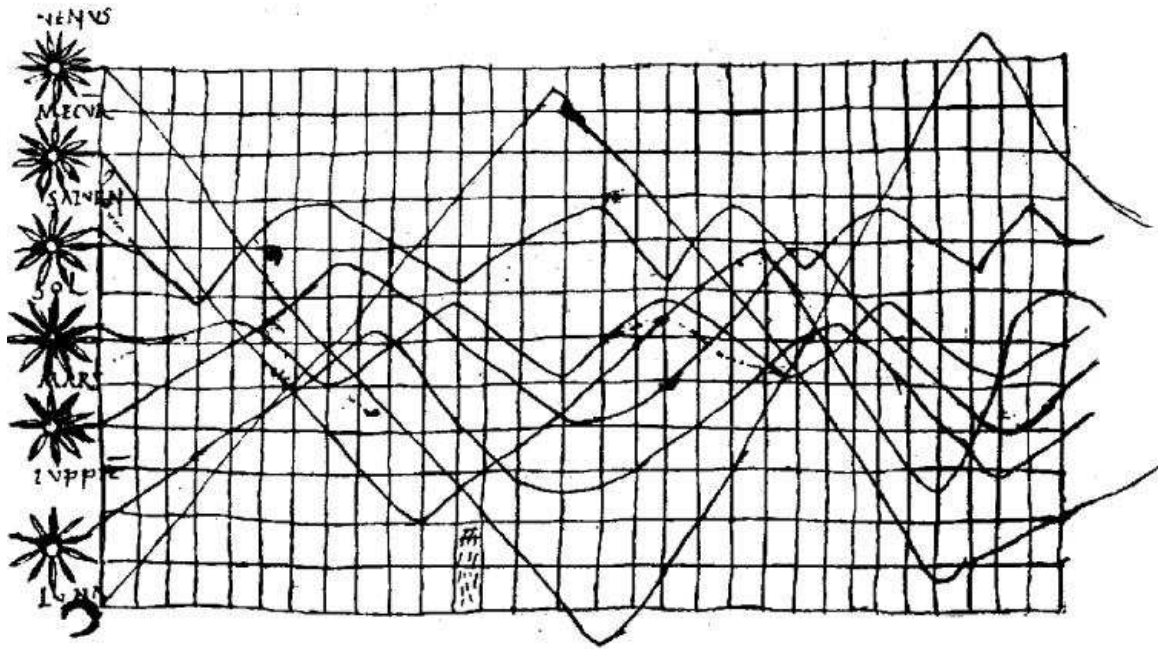


Fig 2: One of oldest known examples of information design, depicting planetary movements over time. 10th Century. Author unknown.

From these first appearances of graphs and diagrams, few new forms emerged until the time of William Playfair, who is widely considered to have invented or improved upon most of the graphic forms used in visualization today, including the line graph, circle graph, bar chart, and pie chart (Tufte, 9).

Following Playfair, innovations in graphic forms and their use in science, statistics, economics, and social planning flourished throughout the 1800s with many important thinkers at the time using graphs and diagrams to support their ideas. In 1858 Florence Nightingale modified Playfair's pie chart to create the famous rose diagram (Fig 3), which

she used to show that more British soldiers died from disease (the largest, outer pies) than battle wounds (the smallest, inner pies) in the Crimean War. The diagram was a compelling visual argument in Nightingale’s campaign to improve sanitary conditions for the soldiers (Friendly, 14-15).

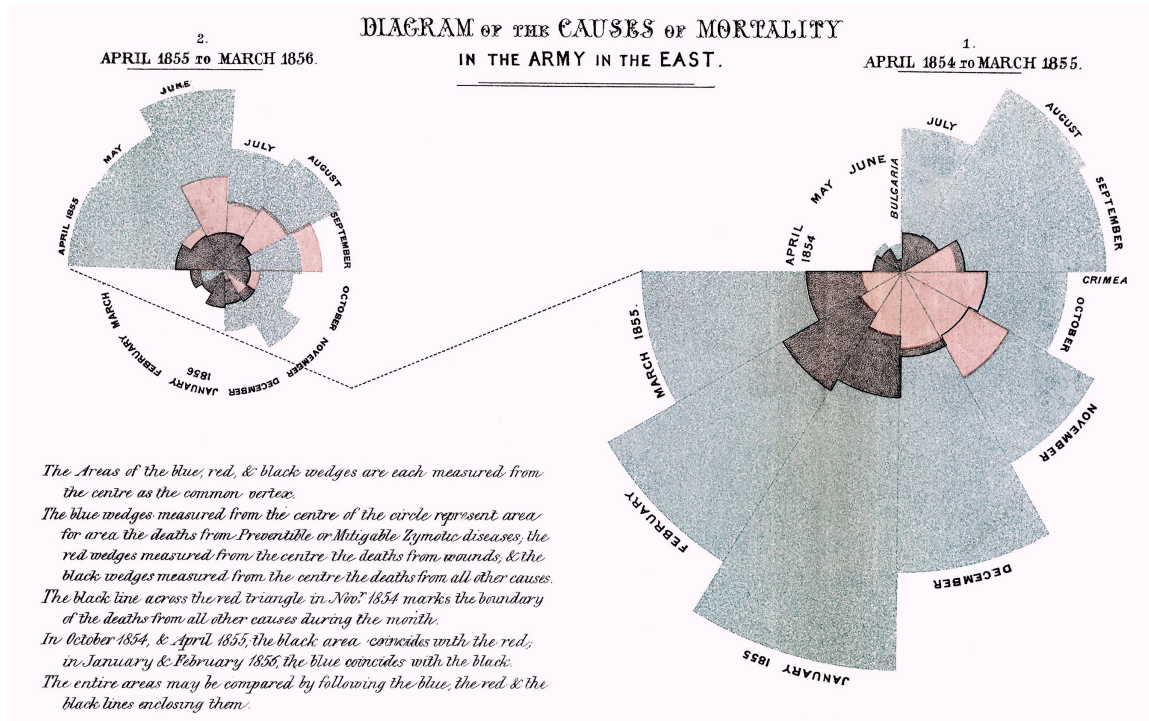


Fig 3: Diagram of the Causes or Mortality of the Army in the East (1858) by Florence Nightingale.

Another renowned graphic from this time is John Snow’s cholera dot map that he created during an outbreak in Soho, London in 1854 to prove his theory that the disease was waterborne (Fig 4). Prior to Snow’s map, city leaders assumed the cholera outbreak was caused by the odor of human waste that had built up on the streets due to city sanitation services not coping with rapid population increase (Ferster, 4). By geographically plotting all the recorded cholera deaths on a neighborhood map of Soho, Snow was able to show that source of the outbreak could be localized to a public water pump on Broad Street. Authorities subsequently disabled the pump, attesting to visualization’s power to persuade,

and the dot map became the founding innovation for modern epidemiological mapping (Friendly, 12).

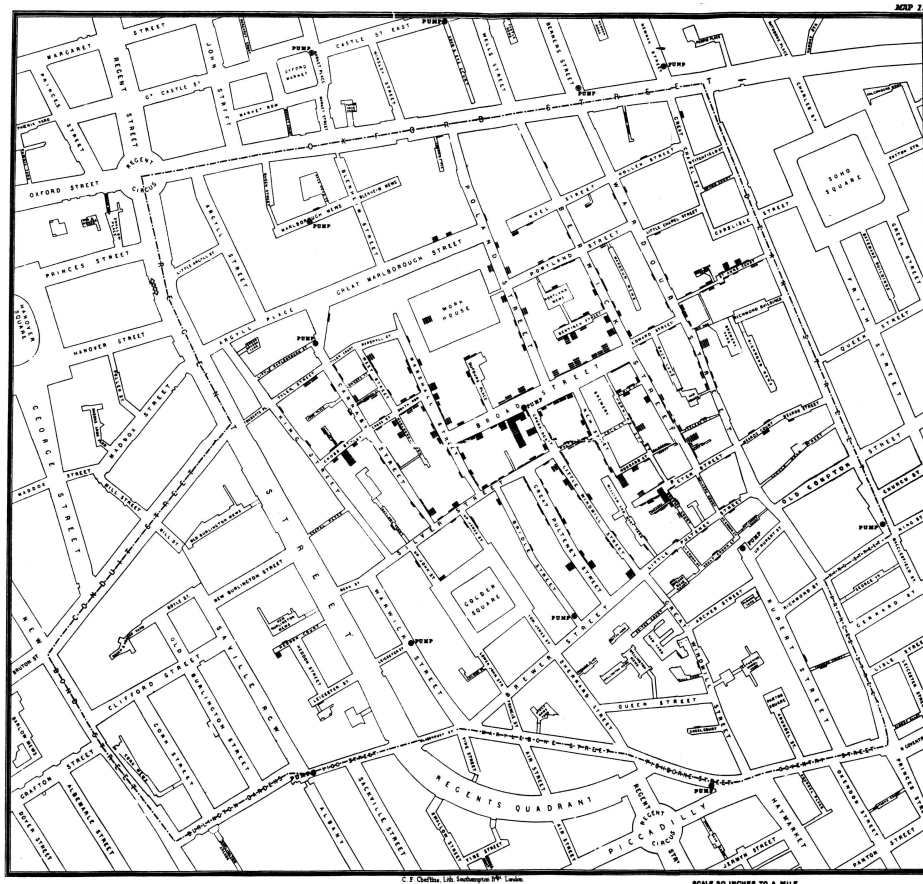


Fig 4: Spot map of the Golden Square outbreak (1854) by John Snow.
Source: John Snow Archive and Research Companion.

The rapid developments in graphing techniques during this time are attributed to the sudden availability of large data sets from new state statistical offices that were established across Europe, a sign that there was growing recognition for the importance of numerical information in state planning. Many of these offices also released publications featuring graphic representations of their data with careful consideration to composition and aesthetic, one of the most notable being the *Albums de Statistique Graphique* produced by the French ministry of public works from 1879-1897 (Fig 5).

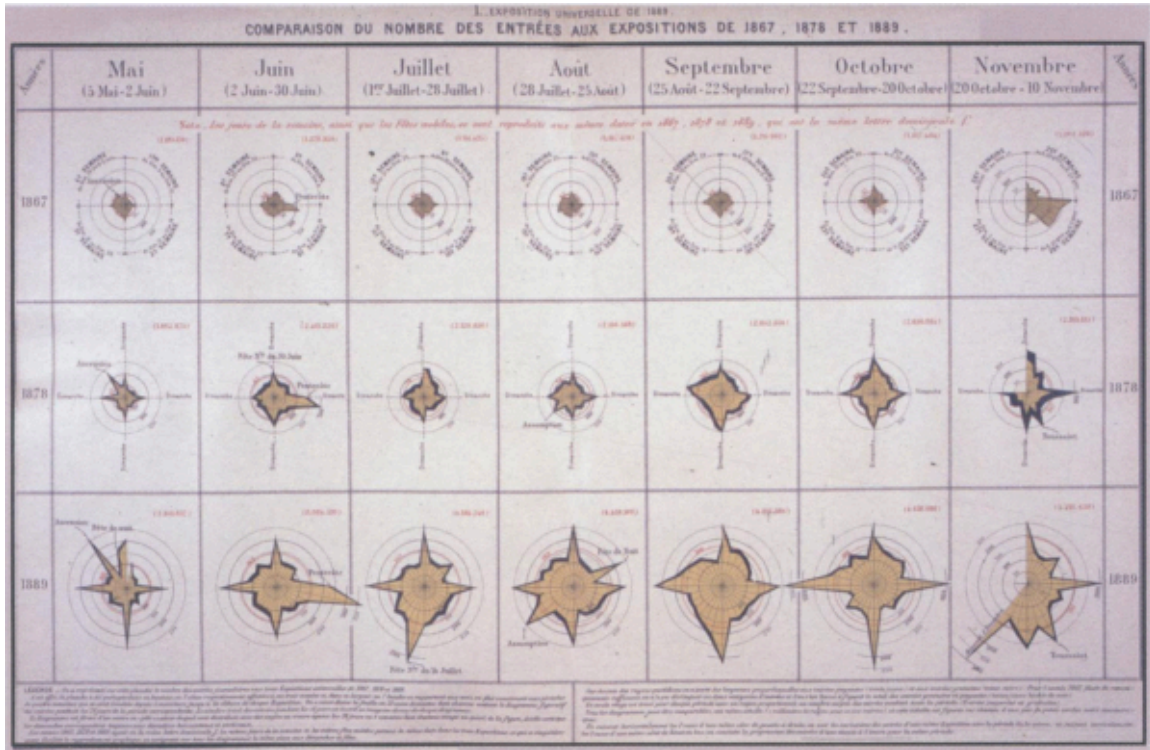


Fig 5: Diagram from the Albums de Statistique Graphique, 1889: *Comparison of the Numbers Attending the Expositions of 1867, 1878, and 1889.*

Published in colour as large-format books, the *Albums* were a pride of the French people and statisticians, an exquisite collection of all the graphical methods of that time, often with innovative adaptations specific to their subject matter (Friendly, 17-18).

At the turn of the 20th century, however, many of these statistical publications, including the *Albums*, were discontinued due to the high cost of production, and the enthusiasm of the 1800s matured into more formal models of mathematical graphing. Over the next several decades, while innovation remained relatively stagnant, the use of statistical graphics became common practice, entering the curriculum and mainstream application (Friendly, 20-21). Dormancy continued until 1962 when a landmark paper “The Future of Data Analysis”, was published by John W. Tukey, called for the recognition of the practice as a legitimate field separate from mathematical statistics (Friendly, 23). Tukey’s

later work in Exploratory Data Analysis (EDA) introduced new graphic techniques that used “pictures to give rapid statistical insight to data,” and reignited experimentation in visualizing data (Card et al., 7). In 1967, the French cartographer Jacques Bertin published the influential *Semiologie Graphique* in which he developed a comprehensive theory for graphic representations that focused on graphs whose functions are to store, communicate, and process information (Ferster, 32). Bertin further provided an important organizational structure for the field by assigning features and relationships of data (distribution, ranking, correlation, geospatial, etc.) to appropriate visual and perceptual elements of graphics (points, lines, proximity, hierarchy, maps, etc.) (Friendly, 23).

Just as the theoretical exploration of graphing data was picking up in the late 1960’s, computers were introduced as a tool for processing statistical data. The application of computers was a transformative development in the discipline and one which would eventually come to define information visualization. With computers came new paradigms, languages, and software for visualizing data, leading to exponential growth in methods and techniques (Friendly, 24). However, as with many new technologies, fascination with the computer’s capabilities attracted early designers to use superfluous graphic elements, which may have shown off the technology, but did little to improve the viewer’s comprehension of the data. It was in 1983 that Edward Tufte sought to put an end to what he referred to as ‘chartjunk’ with his Theory of Data Graphics.

In the first of his canonical books, *The Visual Display of Quantitative Information* (1983), Tufte criticizes “the interior decoration of graphics,” referring to the geometric patterns often used to fill in bars and charts, overuse of grid lines, pointless three-dimensional perspective, and any other unnecessary decorative forms (108). To guide future practice Tufte proposes five principles to adhere to (within reason) that continue to

be fundamental to the field: “Above all else, show the data. Maximize the data-ink ratio. Erase non-data ink. Erase redundant data-ink. Revise and edit” (105). Although the use of computer generated graphics has made ‘ink’ less relevant, the point remains that every graphical element should have a purpose and should only be there for the sake of accurately and effectively communicating the data it represents. In many ways, Tufte’s theory picked up on the functional rationalism of mid 20th century graphic design movements like New Typography and International Style. Jan Tschichold of New Typography advocated for the abolition of the ornamentation, infamously stating that form must be created out of function (Tschichold, 36). Leading into the era of International Style, Beatrice Ward introduced the concept of ‘The Crystal Goblet’ which likened optimal typography to a pane of glass, beautifully built yet transparent, allowing the viewer to focus on the content rather than the type itself (42). Similarly, Tufte saw incredible beauty in the effective visual communication of information using the simplest forms, noting “graphical elegance is often found in simplicity of design and complexity of data” (177).

Current Practice: a balance of form and function

The theoretical work of Tukey, Bertin, Tufte, Card, MacKinlay, and Shneiderman from the 1960’s to the 2000’s created the foundation for a new discipline that has become critical to how we manage and understand the flow of data being produced at exponential rates. Information visualization continues to draw a myriad of new contributors with fresh ideas for its application across disciplines, resulting in a broad range of purposes, technical levels, and aesthetic considerations. Numerous subfields have been proposed that seek to define different types of information visualizations being created along this spectrum of characteristics. Two of particular interest to my research are *Casual Information Visualization (Casual Infovis)*, which distinguishes non-traditional visualizations that exist at

the boundaries of information visualization and other disciplines, and *Information Aesthetic Visualization*, which recognizes the role of aesthetics in information visualization.

Introduced by Zachary Pousman, John T. Stasko, and Michael Mateas in 2007, casual infovis encompasses what they describe as 'edge cases' in relation to the core of common information visualization. Pousman et al. make a distinction between 'traditional' and casual infovis based on differences in the user population, the pattern of use, the data being visualized, and the type of insight the users acquire. In contrast to traditional information visualizations that are typically created for specific expert groups in task and analysis work situations, casual infovis is the visual depiction of information that has personal meaning for everyday users in work or non-work situations (5). Visualizations in this subfield may be functional or ambiguous, using an artistic approach to convey additional meaning beyond the data (7). Although casual infovis encompasses artistic visualization, it does not use 'aesthetic' as a differentiator from traditional visualization. However, the differences in purpose (users, use, data type, and insight) make aesthetic an important consideration for how to appeal to an everyday user group. In making this comparison between attention to aesthetic and a lack thereof, a dichotomy emerges where traditional visualizations focus on functionality, often neglecting aesthetic presentation (Scagnetti, 7), and artistic visualizations focus on subjective expression and experimentation, visually abstracting the information in favour of aesthetics (Lau and Moere, 1). Attempting to bridge the gap between aesthetic in traditional and artistic visualizations is the subfield of *Information Aesthetic Visualization* introduced by Andrea Lau and Andrew Vande Moere. This approach suggests that the aesthetic should be thought of as an "independent medium that augments information value and task functionality" (1). From a design perspective, this places the

intent of aesthetics as a method to reveal another layer of meaning behind the data it is representing, thus *reinforcing* functionality rather than impeding it.

A visualization that would be considered both casual and information aesthetic is *Notabilia* (2010) by Moritz Stefaner, Dario Taraborelli, and Giovanni Luca Ciampaglia, a visual depiction of deletion discussions on Wikipedia (Fig 6).



Fig 6: *Notabilia: Visualizing Deletion Discussions on Wikipedia* (2010) by Moritz Stefaner, Dario Taraborelli, and Giovanni Luca Ciampaglia. Source: Notabilia.net.

Each line in the graphic represents one discussion that was nominated for amendment or deletion, arguments for keeping the article are in green and curve the line left, arguments for deletion are in purple and curve the line right. This formula results in two tree-like structures, 'The Deleted' and 'The Kept,' that the user can browse through to see the titles of the articles in question. *Notabilia* would be classified casual based on the target audience of Wikipedia users (general public), the often non-work related usage, the social/cultural nature of the data (Wikipedia deletion discussions), and the reflective insights users will acquire. Its functionality is further supported by aesthetic due to how the striking visual appeal of the lines, all uniquely waving and curling, intrigues the user to explore each one to

discover what topic lead to creating its shape. Beyond understanding how these discussions transpired, the design aesthetic of *Notabilia* suggests an organic quality to the back-and-forth of deletion discussions.

For the application of these subfields to the practice of information visualization, a framework by Manuel Lima provides an approach to information visualization that supports the development of both functionality and aesthetics. Lima, author of *Visual Complexity: Mapping Patterns of Information* (2011), breaks the information visualization process into three main stages in his Information Visualization Framework: 1) data transformation, 2) visual mapping, and 3) interactive framing (Fig 7).

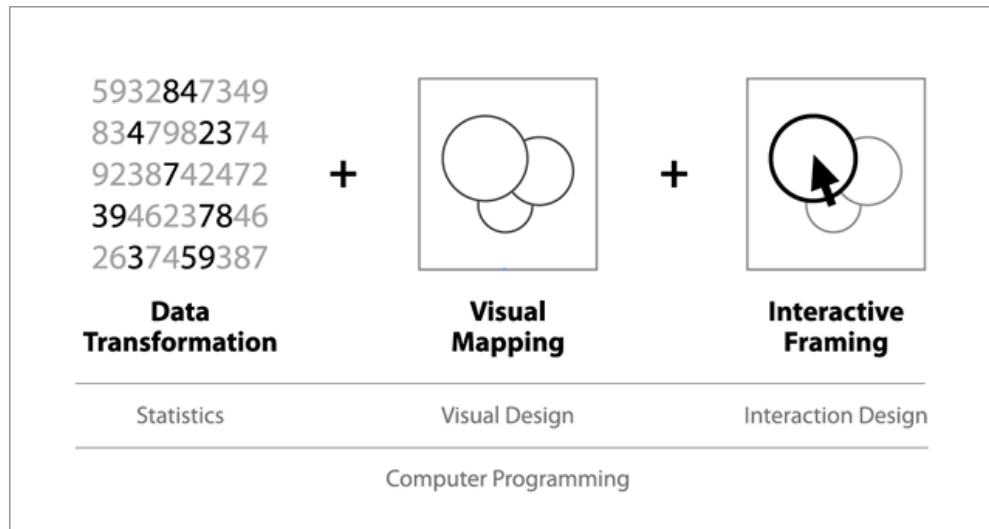


Fig 7: *Information Visualization Framework* (2011) by Manuel Lima. Source: visualcomplexity.com.

Data transformation relies on gathering, analyzing, and mining data to provide the essential foundation of any visualization. Visual mapping refers to the data being given a deliberate visual form based on the intrinsic purpose of the visualization and how and where it will be used. The third component, interactive framing, is considered to be the unifying layer, critical for providing explorative analysis for the user (Lima). On the importance of interactivity in information visualization's use as a discovery tool, Lima states

"interactivity provides the final coalescing layer for exploration [...] enabling users to inquire, filter, manipulate, reshape, and examine the visual outcome in order to identify properties, relationships, regularities, or patterns" (Lima).

Contrary to traditional information visualization as described by Pousman et al., Lima's framework invites greater input from graphic and interactive designers who can bring consciousness to how aesthetics supports the functionality. In addition, by identifying these three stages of information visualization, experts relative to each stage have a greater opportunity to contribute their specialized skill-set to the project, achieving optimal end results.

In examining the nature of 'expertise' in the context of information visualization, the three stages outlined by Lima become linked with their respective disciplines; data transformation with data science, visual mapping with art and design, and interactive framing with computer programming. However, what isn't identified in this framework is a stage and expert in the dissemination of the work, an aspect that is critical to the core objective of information visualization. To determine what expertise this role would entail, it is important to distinguish between 'specialist tacit knowledge', which involves advanced practical competence gained through immersion in a specialist domain, and 'ubiquitous tacit knowledge', which can be acquired by almost anyone through everyday experiences. While expertise on subjects like climate science and design is typically gained as specialist tacit knowledge, expertise of the target audience, which may include lifestyle, perceptions, common experiences, or values, is usually gained as ubiquitous tacit knowledge through immersion in the target group; that is, by identifying as a *member* of the target group (Ross, 915). For information visualizations intended for wide public dissemination, audience expertise requires knowledge of the general public who are considered non-experts on the

topic. In Lima's framework, the visual mapper and interactive framer would be closest to the audience's perspective, rather than the data transformer whose specialist tacit knowledge of the data distances him or her from relating to how the audience will see and understand the content as non-experts. Positioning the visual mapper and interactive framer of the information visualization as the expert of the audience then allows their experience of learning the content to inform how they design the visualization; they become experts in how to comprehend the data from a non-expert perspective.

By acknowledging these points of expertise, each member of the team can contribute in meaningful and fulfilling ways while also trusting the others' contributions to accomplish their mutual goal. Due to the range of expertise that is necessary to fulfill the demands of each stage, information visualization has become a practice rooted in multidisciplinary collaboration. Most variable is the expert role that applies to the data transformation stage, which, depending on the topic may be filled by a wide variety of disciplines from the sciences and social sciences that do not traditionally collaborate with designers, artists, or programmers. In order to navigate what will often be new territory for their members, multidisciplinary groups approaching information visualization projects need to establish collaborative methods that build trusting and productive relationships.

Information Visualization of Wicked Problems

In 1973 designers Horst Rittel and Melvin Webber introduced the concept of *wicked problems*, a class of problems in society that are exceptionally complicated, ill formulated, contain confusing information, involve decision makers with conflicting values, and where the ramifications of the system are difficult to understand. Characterized by their complexity, interconnectedness, and the fluctuation of their components, wicked problems are best known for their resistance to resolution due to the indeterminacy these factors

cause (Buchanan, 15). The subject of my research project, climate change, is a particularly notorious wicked problem, and has even been dubbed super-wicked by social scientists (Lazarus, 10750; Levin, Cashore, Benjamin, Bernstein, and Auld, 502002). According to Levin et al., this escalation in the wickedness of the problem is due to climate change's time sensitivity, lack of a central authority, tendency for decision makers to weight present gains over future losses, and that those seeking to resolve the problem (humans) are also, in part, responsible for causing it (through industrial era carbon emissions). (Levin et al., 502007).

While tools and strategies for communicating the realities of climate change have been widely published online since the issue gained widespread public attention in the last decade, the first comprehensive text on the visual communication of climate change, *Visualizing Climate Change* by Stephen R.J. Sheppard, only emerged in 2012. For Sheppard, the lack of effective action in policies, economic incentives, laws, and behaviors that address climate change is due to barriers in how we perceive the problem. He argues misperceptions about climate change, perpetuated in the media and our communities, cause confusion, complacency, ignorance, unpreparedness, disconnections, and a lack of personal accountability. There is also a disconnect that exists in our minds between what scientists say is happening and what we see in our immediate surroundings. In order to address the lack of effective action, we must first overcome these social and perceptual barriers that prevent us from seeing climate change as a serious problem requiring urgent solutions (Sheppard, 14-16).

In "Shaping Belief: The Role of Audience in Visual Communication", Ann C. Tyler argues that in order to shape beliefs or perceptions through visual communication, it is essential to understand the relationship between audience and the communication goals (21). Tyler suggests that when attempting to persuade through communication, the

audience becomes elevated from a reader to a dynamic participant in an argument. In this relationship, the designer of the visual communication must then take into account that, as a participant, the audience brings an existing set of beliefs to the argument (Tyler, 22). For interactives like information visualization, the need for the audience to also physically participate with the work in order to get the complete story compounds the necessity to consider how existing beliefs will affect the decisions people make while interacting.

Both Sheppard's call for effective visualizations to rectify the public misperception of climate change and Tyler's belief that effective visual communication lies in understanding the relationship with the audience underscores the potential for information visualization to be used as a method for communicating the super-wicked problem of climate change. In the next section, I discuss the challenges of data literacy, information apathy, and bias that have informed how I conceptualized and designed information visualizations of climate data.

Analysis of Audience and Wicked Problems

In this section, I focus on three main challenges that often exist in the interaction between information visualizations of wicked problems and their audience:

- 1) Data literacy
- 2) Information apathy
- 3) Bias

Based on previous research by design theorists, information visualizers, social planners and activists (some of whom I will refer to below), these three issues emerge as critical to consider when approaching the creation of information visualizations of wicked problems. With climate change as the case study of my research project, I examine the way these issues exist when presenting climate change visualizations and thus, effect the audience that my project seeks to engage – the general public in Alberta.

It should be noted that the pragmatic goal of my research is to broadly disseminate climate change data to all Albertans, who I consider the audience to be non-experts on the topic; the majority will not have anything more than a general knowledge of climate change and how to decode climate change information visualizations.

Data Literacy

The audience's ability to decode the visual representations of data in information visualizations is what is referred to as data literacy. According to Frances R. Curcio, data literacy is the ability to read the data, read between the data, and read beyond the data (Friel, Curcio, and Bright, 130) with each stage related to progressively deeper levels of understanding. With the world producing data at exponential rates, and information visualization being one of the primary methods for its communication, being literate in this visual language is crucial to access the many insights this data reveals. Access to

information through data literacy is an ability that is universal and global, as information visualization is not tied to features of a particular spoken or written language (Tufte, 10).

During a keynote address at the 2012 Strata Conference Kim Rees insists that, for non-technical audiences, data literacy can be achieved more effectively when highly technical visualizations are mediated through the design of intuitive visuals and interactions. She argues that to overcome data illiteracy the goal must not be to simplify but to keep people moving at the pace of data through education. To Rees, it is a matter of giving people the opportunity to become familiar with information visualization by providing them with positive reinforcement as they explore unknown territory ("The Dirty Truth About Data Literacy"). Edward Tufte further supported this idea in a recent interview stating, "in general audiences are a lot smarter than a lot of people think. So, it's not know your audience; it is respect your audience and really know your content" ("The Art of Data Visualization").

Based on Rees and Tufte's confidence in the audience's ability to decode data when they are given the opportunity, it is up to the designer to present the data in a way that allows the audience to easily develop new capabilities for reading information visualizations. The objective to not only educate through the content but also through the visual representations themselves is a tall order, but information visualization does have a unique advantage over linear or static forms of data visualization – its interactivity. Interactivity allows for information to be layered so that exponentially more detail and explanation can be given and the user is able to select the most relevant narrative, all while maintaining a clean composition. Through visual cues, the user can be guided through an interactive and, therefore, through the information, creating a flexible narrative for the user to follow and be introduced to additional, and potentially more complex, data over time.

Both visual and non-visual tactics can be used to facilitate the narrative including visual structure, highlighting, transition guidance, ordering, interactivity, and messaging (Segel and Heer, 7).

Telling a story with information visualization differs from the tightly controlled progression of traditional storytelling, in that its interactivity invites verification, new questions, and alternative explanations (Segel and Heer, 7). However, in determining a narrative structure in information visualization, there still exists a wide range between an explanatory visualization, with a delivered narrative for the uninitiated, and an exploratory visualization, with an open narrative for the expert (Strausfeld). It is a spectrum that the Bloomberg Visual Data Team discussed in a recent presentation where they suggested the ideal is to offer both explanation and exploration, the level of each dependent on the data and the target audience (Strausfeld). In this realm multiple narratives can coexist: the explanatory narrative that determines the main sequence of events (or the sequence of opportunities to access different pockets of information), and the exploratory narrative, where users are free to choose or potentially manipulate the data to find the story that is most interesting or relevant to them.

When addressing wicked problems like climate change, data literacy becomes increasingly important since the information visualizations tend to be more complex as a reflection of the complexity of the topic. Sheppard claims that one of the reasons climate change communication has been ineffective is due to “a general inability to translate the data into a more meaningful, attractive, and accessible form of information for ordinary folk” (35). Through information visualization narratives, climate change information can become more accessible through the explanation of the complex components while also more

meaningful and attractive by allowing the user to explore the find data that best meets the criteria of meaning and attractiveness for them.

Information Apathy

The abundance of information we are exposed to and the incessant calls-to-action have made many apathetic towards much of the daily communication attempts made by static and interactive media. In the past few years the excessive proliferation of ‘infographics’ on what seems like every topic imaginable, from “Over or Under: the great toilet paper debate” to “Contradictions in the Bible” (see Appendix A), has greatly diluted the initial impact that infographic communications once had. According to Sheppard, one of the reasons climate change has had a difficult time competing for public attention is that it may be out-competed by more immediate or compelling ‘crisis’ information (here he includes an image of a tabloid magazine cover with headlines like “CRISIS!” and “Love Trouble: Angelina won’t stop calling her ex”) (32). While the magazine example might only pertain to a segment of the population, it speaks to the limits of public attention that climate change communications are competing for.

In *Visualizing Climate Change* (2012), Sheppard focuses on three key principles for communicating climate change that he argues will begin to rectify misperceptions and disconnects in public opinion:

- 1) ***Make it local:*** *focus on the local community perspective in dealing with climate change.*
- 2) ***Make it visual:*** *harness the special power of visual perception and imagery in thinking about climate change.*
- 3) ***Make it connected:*** *look at the whole carbon cycle and multiple aspects of climate change, to see the big picture and not just climate change impacts. (43)*

Sheppard's principles are about creating relevance and making the existing evidence visible, as well as stimulating, by appealing to people's sensory perceptions, which can be thought of as a process of data gathering, transfer and interpretation in the brain (33). In this sense, the world, as we see it, is data visualization in its most natural form, highly detailed and complex, but one we have learned to interpret effortlessly. Relating the invisible climate change data to the powerful sensory understandings we all have of our local surroundings would help bring greater meaning to the idea of it changing, an important step towards overcoming information apathy.

The caveat to contextualizing information visualizations is that it must under no circumstances mislead or misrepresent the data itself. In the next section, I discuss how biased communication objectives can undermine the credibility of the information and risks further inflaming bias in the audience they seek to persuade.

Audience and Author Bias

Data literacy goes beyond audiences being able to comprehend and gain insight from visualizations. It also involves awareness of inherent biases that occur on behalf of both the author and the audience of the visualization.

For audiences, bias often takes the form of *confirmation bias*, where the audience subconsciously (or consciously) looks for evidence in a visualization that confirms their own beliefs rather than challenges them. Edward Tufte sees this as one of the ultimate challenges of information visualization, that it is economizing for the brain to confirm current understandings rather than learning something new (“The Art of Data Visualization”). Confirmation bias is particularly problematic when the topic is controversial, unconventional, and/or opposing viewpoints have polarized the audience. This is especially true for my research project, as Alberta is a region where the topic of

climate change has become extremely polarized and political. The debate here has created an environment where the population is pressured to either 1) believe that climate change is at least in part due to human activity and we must correct our practices, or 2) support the oil industry as the core of Alberta's economy. When this level of bias is present, the question of how to design information visualizations so that the audience accurately interprets the information being represented becomes of critical importance.

From the author's perspective, when communicating information that is suggested to be scientific or 'factual,' the presentation should be as honest and transparent as possible. Once audiences become more data literate, any inkling of inveigling or misrepresentation will spark uncertainty and the credibility of the information will be lost. However, even when a visualization appears to be accurate, it cannot be forgotten that data has been through a process of interpretation by the author. 'Educational' material has had design principles attached to it that have been in practice for decades. In "Shaping Belief" Ann C. Tyler's points out that when communicating factual information, it should appear "stable, unchangeable... without expressive characteristics that might suggest individual authorship" (26). In doing so, the audience becomes a more passive consumer to the "omniscient voice of science" (Tyler, 26), which is especially problematic when data has been well designed, but mishandled. The visualization and design community is largely aware of this issue. In the "Information Visualization Manifesto" (2009), Manuel Lima warns, "information visualization, as any other means of conveying information, has the power to lie, to omit, and to be deliberately biased" (VC Blog). Designer Paula Scher has been extremely critical of data visualization, calling it the "world's most effective form of propaganda," labeling it 'faux info' that seduces the viewer with the appearance of infallible, computer generated, scientific authority (The Huffington Post).

Audiences must be aware that the information has been collected, selected, and designed by people (sometimes many), that biases can influence the visualization at every stage, and that all visualizations should provide them with means to determine the credibility. Likewise, information visualization designers, as ambassadors of information, must be acutely aware of how our own biases may affect our visualizations and the accuracy of the representation. Although raw data may not reflect a particular belief system, both the act of designing and the act of viewing involves interpretation, which is influenced by perspective, analysis, and judgment (Tyler, 21).

Some might argue that attempting to present information visualizations on climate change with neutrality and objectivity conflicts with another concept relevant to my research – designer as author-activist. Design authorship refers to designers taking agency to work outside of the client-designer relationship and become the author of the work they create (McCarthy, 1166). In this realm, the motivation to make the work is often inspired by "a personal concern for world problems, and an active interest in issues that have an impact on the individual, society and the planet as a whole" (McQuiston, 6), implicating a distinct bias in the designer as author-activist. Is it possible for a designer to present information objectively when they have a significant emotional investment on one side of the debate? Recently, Steven McCarthy explored what it means to be a designer as author-activist by shifting the analysis from the design artifact to the contextual milieu in which it was created and implemented (1166). In this distinction the designer and the work are not one in the same, suggesting the ideals of a conscientious designer author-activist can be viewed separate from their work and produce objective information visualizations. In such a case, I do not believe objectivity removes activism but that it still exists in the form of overcoming bias. The act of making the information accessible, or 'liberating' it, through comprehensible

visualization so audiences are better informed on an important topic could also be considered the expression of activism.

Information Visualizations of Climate Data: Research Through Practice

This section explains my methodology and process for creating a series of information visualizations on climate change data for my MFA thesis project. The work is an exploration of the research question: *In what ways can design methodologies be applied to the practice of information visualization in order to mitigate the challenges of data literacy, information apathy, and bias when communicating information on wicked problems?* Each visualization takes a unique approach to answering the question, resulting in a range of aesthetics and interactive formats that address data literacy, information apathy, and bias to different degrees. When presented together, the visualizations are designed to compliment each other and become a part of a larger narrative.

Methodology: The ASSERT Model

While Lima's Information Visualization framework of data transformation, visual mapping, and interactive framing offers a breakdown of stages related to expertise, for the production process I look to the ASSERT model by Bill Ferster that includes additional stages for concept development and dissemination. Created in response to a perceived lack of a comprehensive model that addressed the full scope of production of information visualizations, stages in the ASSERT model include:

- 1) *Ask a question.*
- 2) *Search for evidence to answer the question.*
- 3) *Structure that information to answer the question.*
- 4) *Envision ways to answer the question using data.*
- 5) *Represent the data in a compelling visualization.*
- 6) *Tell a meaningful story using the evidence to answer the question. (40)*

Based off components of its predecessors², ASSERT offers the holistic inquiry-driven approach of science, humanities, and social science research. Of particular interest for my research is that it includes a narrative element that Ferster claims is “crucial to create a compelling communicative experience” (40).

As I have already outlined the first stage of *asking a question* in the previous sections, I will now pick up from *searching for evidence* and discuss the process of finding data to answer my research question by establishing a collaboration with Dr. Stefan W. Kienzle.

A Foundation for Collaboration

My initial interest in creating information visualizations on environmental sustainability is what first lead me to Dr. Stefan W. Kienzle as a source for watershed data of the South Saskatchewan River Basin. Over the course of our first meeting, Dr. Kienzle mentioned another dataset that he and his lab were working on – sixty years of climate records for 6,834 locations across Alberta (see Appendix B). What was intriguing about this dataset was the thousands of individual, and yet equally important stories it told; in the data ranging from 1950 to 2010, Dr. Kienzle had identified trends at each location that showed

² Predecessors cited in the proposal of the ASSERT model include: Ben Shneiderman's *Task By Data Type Taxonomy* (1996), where the structure of the visualization is based on the structure of the data; Ben Fry's *Aquire, Parse, Filter, Mine, Represent, and Interact* (2004), which starts with the collection of data for the purpose of answering a question; Dan Roam's *Back of the Napkin* model (2008) looks at problems through the iterative loop of looking, seeing, imagining, and showing; and Jesse James Garrett's *Elements of User Experience* (2003) that approaches development from a user-centered perspective (Ferster, 33-37).

that Alberta's climate is indeed changing. Perceptions around climate change often revolve around what *will* happen, this data shows it *already is* happening right in our own backyard.

There are several key characteristics of Dr. Kienzle's climate data that further align it with my research interests:

- Requires decoding for the non-expert (promoting data literacy).
- Localized to 10km² grids (more meaningful for people living at each location).
- The topic of climate change is considered a super-wicked problem, with decision makers having conflicting interests, especially in Alberta (wide range of bias in both author and audience).
- Based on daily recordings from the past 60 years as opposed to future projections (opportunity to introduce new evidence to the dialogue).

With the selection of Dr. Kienzle's data came another addition to my research project - a collaborative partner. This would be the first time either of us participated in a collaboration between science and design. In order to navigate through this new territory, we established a trusting collaborative relationship with dialogue that was honest and open, allowing for us to talk through any uncertainties we had regarding our roles and expectations:

DESIGNER

What degree of artistic license do I have with the representation of the data?

Will this collaboration allow me to explore my own research interests?

What authorship will I have over the results?

SCIENTIST

Will scientific integrity be maintained with an alternative representation of the data?

Will this collaboration meet my goals for disseminating my research?

What authorship will I have over the results?

From these initial questions, we found direction in our common purpose – to discover methods to improve communications of complex scientific research to a broad public audience. We also saw the collaboration as mutually beneficial from our different

perspectives. For me, having Dr. Kienzle provide the data would allow my research to focus on the visual mapping and interactive framing stages of creating the information visualizations. The pairing would also give me unfettered access to the expert behind the data who had intimate knowledge of its complex features and the science it represented, a topic I had little knowledge about prior to this project. For Dr. Kienzle, the visualizations would be a valuable resource for students to learn about climate science as well as a way to share his research with a larger audience.

A productive working relationship was established over a six-month period with intermittent periods of close collaboration as the project moved through the stages of concept development, creation, refinement, and exhibition/public release. It was crucial that Dr. Kienzle was able to review the visualizations throughout their development to insure their scientific accuracy.

From this strong collaborative foundation the research project became well positioned to tackle the much larger challenges presented by the data – how to share the climate change data with the public through information visualizations that promote data literacy, avoid information apathy, and accommodate for bias in order to create a greater sense of appreciation and responsibility for our changing environment.

Data Analysis and Background Research

In the third stage of ASSERT, *structuring the information to answer the question*, I began by analyzing one of the ten thousand Microsoft Excel spreadsheets provided by Dr. Kienzle for the grid location at the latitude 50.8017 and the longitude -114.4491 (Fig 8). At the outset, I had no background knowledge in climatology so I relied heavily on Dr. Kienzle and his course documents (Fig 9) to explain the data.

acronym system (125Fd, 141ETR, 143GSL, 191Tx10...). The following sheet showed trend statistics for each index, which included a calculated trend and confidence value⁴ for each index based on the Mann-Kendall trend formula⁵ that averaged the year-to-year variability over all sixty years. The following sheets feature line graphs of each of the indices showing yearly-recorded values (variability) and a trend line. Finally, the last page was a summary of all the data.

Working from the spreadsheets, I created an information inventory to get a sense of the range of data I had to work with. Latitudes and longitude values, the titles of the climate indices (frost days, simple daily intensity index, min Tmax, etc.), annual day counts, millimeters of precipitation, temperatures in degrees Celsius, sixty years between 1950 and 2010, yearly variability records, sixty year trends, and confidence values made up the main body of information. I figuratively refer to each of these data groupings as 'objects' that would require their own graphic representation in an information visualization. For example, a range of years (the data object) is often represented using a horizontal distribution of associated points (the graphic representation). From this full inventory, only a selection of climate indices would be included in the visualizations based on the science behind them and the project's target audience. Many of the indices in the full data set are useful to climatologists but would have little relevance to non-experts. Dr. Kienzle also

⁴ A confidence value is "the validity of a finding based on the type, amount, quality, and consistency of evidence" (Planton, 1451).

⁵ Mann-Kendall trend test is "a nonparametric test to be used when a trend is identified in a series, even if there is a seasonal component in the series" (XLSTAT).

recommended that I avoid using indices related to precipitation due to its extreme variability between years and decades (Diaz, Kulshreshtha, and Sauchyn, 34). Further analysis of each index, including their trend confidences, lead me to focus on six:

- 1) Growing Season Length: Total number of days per year in the growing season. Growing season begins when the daily average temperature is 5°C or higher for at least 6 consecutive days and ends when it is -5°C or less for at least 6 consecutive days.
- 2) Heat Wave Duration Index: Total number of days per year that were a part of a heat wave. A heat wave is when the average daily temperature is 5°C or more above average for at least 5 consecutive days.
- 3) Number of Days TMAX \geq 25°C: Total number of days per year with a daily temperature reaching 25°C or greater.
- 4) Number of Days \leq 0°C: Total number of days per year where the temperature drops below 0°C. Referred to as a *frost day*.
- 5) Number of Days TMAX \leq 0°C: Total number of days per year with a temperature below 0°C all day. Referred to as an *ice day*.
- 6) Number of Days TMIN \geq -25°C: Total number of days per year with a temperature dropping below -25°C.

These indices are all records of annual day counts based on temperature (i.e. 175 frost days in a year), allowing for a common scale to visualize the values with. This list also has equal representation of temperature thresholds above and below 0°C so that patterns in either range have the opportunity to be revealed.

Concept Development

My process of *envisioning ways to answer the question using data*, the fourth stage of ASSERT, started with identifying the relationships between all the data objects. As I referenced Stephen Few's classifications of data relationships in graphs and tables, the complexity of this data set was underscored after realizing there was potential to display all ten: quantitative-to-categorical, quantitative-to-quantitative, time series, ranking, part-to-whole, deviation, distribution, correlation, geospatial, and nominal comparison (Few, 137).

Each type of relationship is best visualized in different ways to reveal the associated insights, so the questions then became: what insights are most important to fundamentally understanding climate change, are the most significant for the audience to walk away with, and would provide literacy of climate data, context for the changes, and faith in the validity of the data representations?

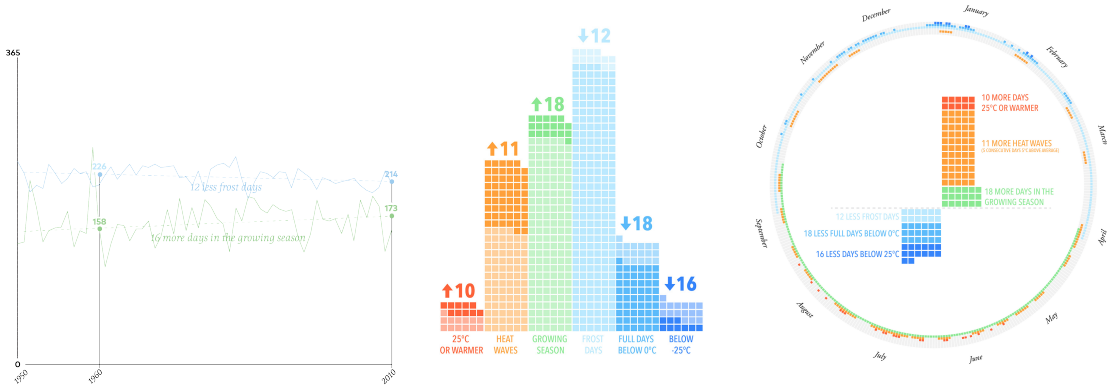


Fig 10: Sketches of climate data from 50.8017, -114.4491

To get a tangible understanding of the data objects and their relationships I conducted quick visual studies that experimented with how different arrangements, visualization formats, and graphic attributes might be used (Fig 10). Working through these iterations revealed opportunities as well as challenges, prompting new, more specific questions and lines of investigation into the data set and possible representation formats:

Some climate indices are increasing and some are decreasing. How can I effectively show two directions of change?

Can I distribute climate index values throughout the year when the data is only a yearly total?

What scale can I limit the data to?

Are the patterns I'm seeing for this location consistent across Alberta?

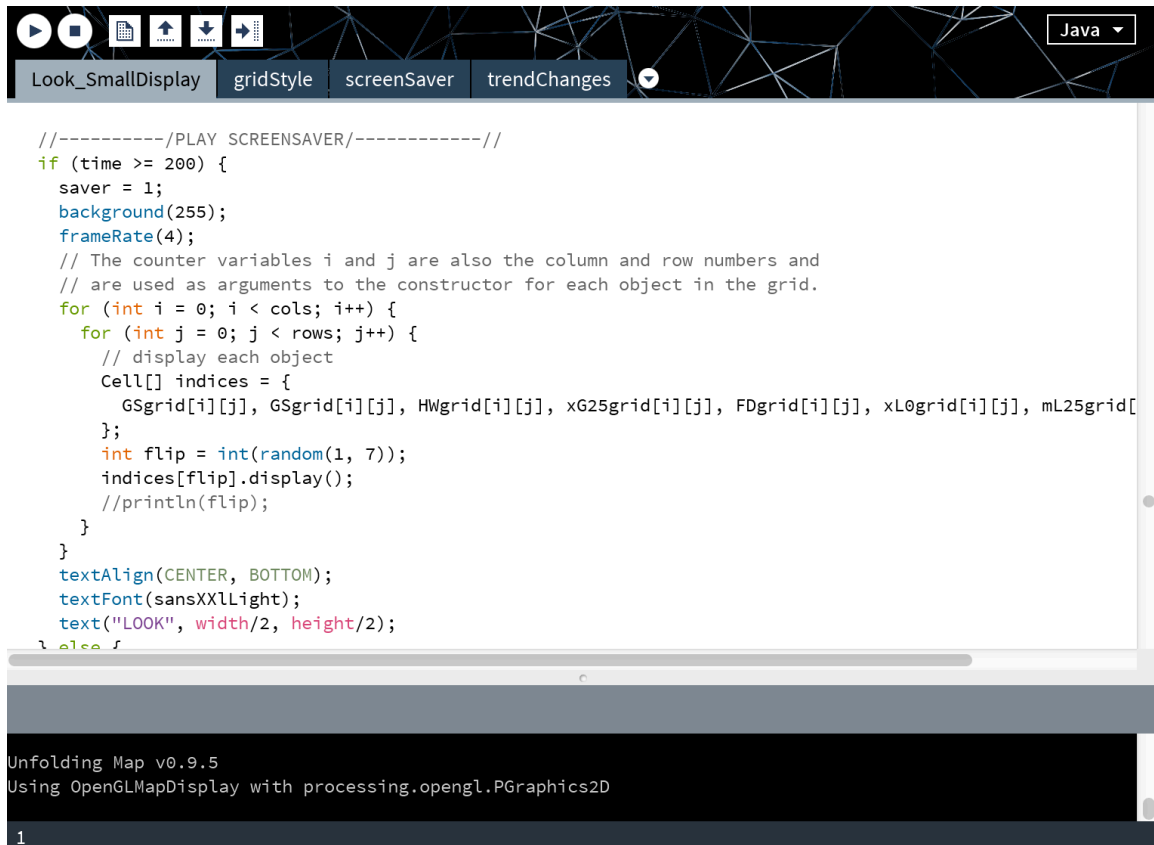
Will these formats work for the variations and deviations in data across the province?

Based on these preliminary studies, I developed a concept for a series of information visualizations that would each explore different ways the data could be presented to address the three challenges of data literacy, information apathy, and bias. The particular qualities of the climate data that relate to these challenges are encompassed in the series titled: *Here / Now / Look / See: information visualization of recent climate records in Alberta*. **Here** speaks to establishing significance in the locality of the data. **Now** speaks to context and bias in that the data is a recent history of recorded values. **Look** speaks to overcoming information apathy and/or bias by activating the viewer and calling them to simply look. Lastly, **See** speaks to data literacy, inviting the viewer to comprehend the information.

With a concept envisioned for how to present the climate data, *Here / Now / Look / See* moves into the fifth and sixth stages of ASSERT, *representing the information and telling a story*. For these final two stages I will discuss the methods used in each visualization in the series.

The Processing Programming Environment

To create the information visualizations I used Processing, an open source programming language and development environment (Fig 11). Created in 2001 by Ben Fry and Casey Reas, Processing is known as a crossroads for programmers and visual artists and has been adopted by tens of thousands of students, artists, designers, researchers, and makers to create visual, animated, and interactive applications, or as they are referred to in this environment –sketches (processing.org).



```
//-----/PLAY SCREENSAVER/-----//
if (time >= 200) {
  saver = 1;
  background(255);
  frameRate(4);
  // The counter variables i and j are also the column and row numbers and
  // are used as arguments to the constructor for each object in the grid.
  for (int i = 0; i < cols; i++) {
    for (int j = 0; j < rows; j++) {
      // display each object
      Cell[] indices = {
        GSgrid[i][j], GSgrid[i][j], HWgrid[i][j], xG25grid[i][j], FDgrid[i][j], xL0grid[i][j], mL25grid[
      ];
      int flip = int(random(1, 7));
      indices[flip].display();
      //println(flip);
    }
  }
  textAlign(CENTER, BOTTOM);
  textFont(sansXXLight);
  text("LOOK", width/2, height/2);
} else {
```

Unfolding Map v0.9.5
Using OpenGLMapDisplay with processing.opengl.PGraphics2D

1

Fig 11: A Processing sketch.

I chose to use Processing for my project due to its visual approach to programming, its capabilities for visualizing data, and the large community of support for visual artists and designers. There has also been a JavaScript library recently released called P5.js that is based directly on Processing, providing a smooth transition between the two environments. Programming with JavaScript allows sketches to be published directly to the web, a platform that will be critical to extending the reach of the climate data visualizations to all of Alberta. This will be discussed in further detail later in this paper in the Exhibition section.

Climate Change in Alberta? A Recent History of Climate Trends in Our Backyards

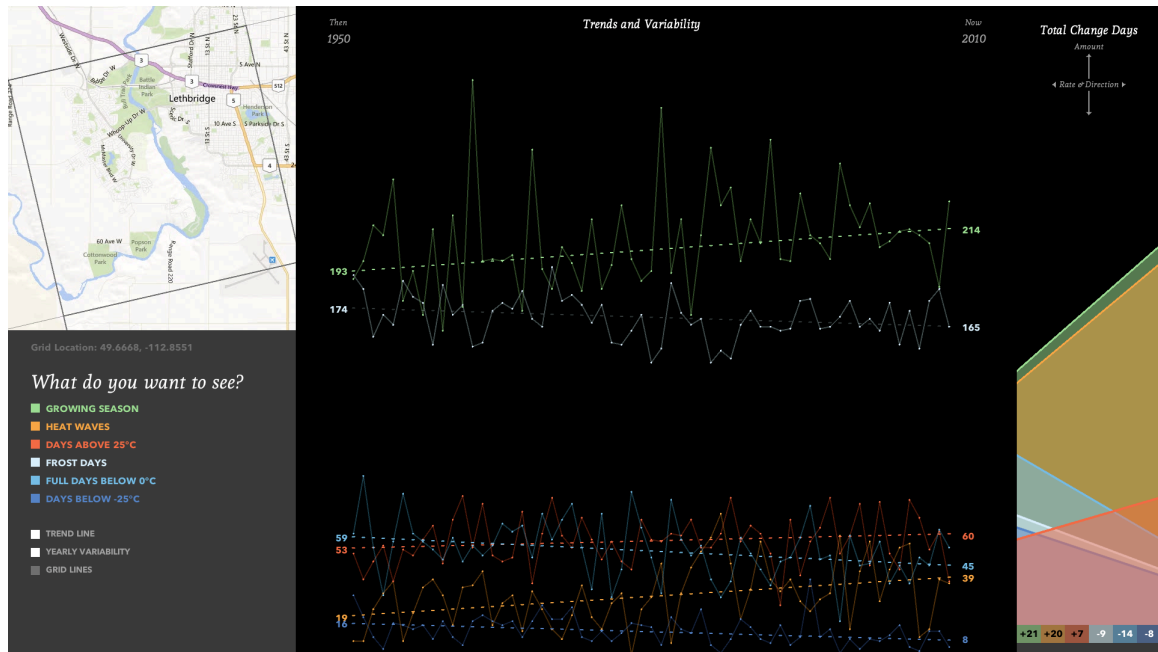


Fig 12: Still from *Change in Alberta?*

I realized early on that the geospatial distribution of the climate data offered a unique opportunity to give all Albertans access to climate data specific to their local area. To expand on the idea of comprehensively representing the selected data set, I designed the visualization to provide the full details of the climate data for each 10km² location. To manage the large scope of information, I used the organizational method from Ben Shneiderman's Information Seeking Mantra: *overview first, zoom and filter, then details on demand* (Ferster, 34). This breakdown formed a basic narrative through which to progressively introduce features of the data in increasing detail.

The first step for the user is to select a location to look at. To facilitate this, the grid of locations was geographically positioned on a map of Alberta so the user could see the boundaries of each section. Once one of the grids is selected, the map zooms into that position and presents the user with the next task: choosing which of the six climate indices

they would like to see data of. As the scientific explanations for each of these indices are mostly unknown by the general public, a brief description of each one is available by clicking for more information.

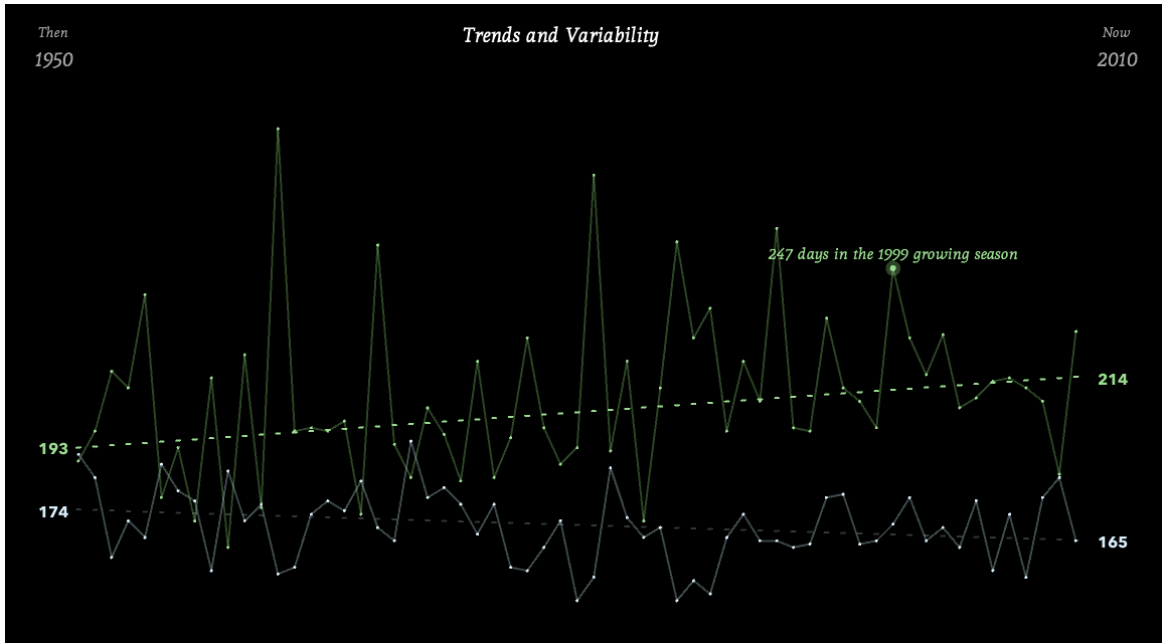


Fig 13: Detail of Trends and Variability in *Change in Alberta?*

When the user selects an index, point values of the yearly-recorded values and the sixty-year trend line are plotted along an x and y axis, where x is a sixty year range and y is the amount of days (Fig 13). The yearly-recorded values result in the variable distribution and occasional deviation and are connected by semi-transparent lines to indicate their order. The numerical value and year of the point are provided when the user selects it. Labels are given to the trend values in 1950 and 2010 to how the slope of the trend line corresponds to the numerical amount of change over time. These values also give the user a scale reference for the rest of the graph, allowing for a de-cluttered interface, although an option to see more detailed grid lines is also available to the user.

Supplementing the graph of the yearly records and sixty-year trend line, is a non-traditional visualization of the amount of change in the trend for each index. Features of convex quadrilaterals⁶ are used to represent the amount of change (tall = more, short = less), the direction of the change from left to right (sloping up = an increase of days, sloping down = a decrease days), and the rate of change (steeper slope = more change over time). The resulting quadrilateral for each index is layered to create a composition that displays a ranking and nominal comparison of climate trends that are unique in each location (Fig 14).

Once the components of the visualization are introduced to the user, they are free to explore the data, seeing how the six climate indices are changing in their area of interest and comparing them in different locations across the province.

The title for this study, *Change in Alberta? A Recent History of Climate Trends in Our Backyards*, which is featured in a title frame at the start of the interactive, alludes to how the visualization approaches information apathy through context and bias through objectivity. In this study the data is contextualized in three ways: by



Fig 14: Detail of Total Change Days in *Change in Alberta?*

⁶ A convex quadrilateral is a polygon with four sides and four internal angles equal to or less than 180 degrees.

immediately identifying that it is specific to Alberta, by establishing it is of the two most recent 30 year climate periods, and by further localizing it to an intimate, and therefore significant, concept of land stewardship; our 'backyard.' Beginning with the title frame, the visualization also attempts to neutralize bias in the audience by first proposing change as a question that needs to be answered, followed by the indication that the data is made up of recorded values, hopefully removing skepticism associated with future projections. Throughout the explanations and visualization of the data, I tried to avoid making any suggestions about climate change beyond what the data shows. The one element that is affected by the design of the visualization is the degree of the incline for the trend changes. By increasing or decreasing the height of the vertical scale, you can change how steep a slope is and affect the way the viewer perceives the amount of change. To distance myself from determining the scale and therefore the slope, I let the height of the display determine the maximum height of the scale so the data would be plotted based on display size. As well, no textual assessment is made on whether the resulting patterns are big, small, significant, or alarming. Through these tactics, I try to leave it up to the user to make value associations based on their own understanding and perception of significant change.

Here | Now | Look | See

This visualization is composed of four smaller studies that explore concepts specific to each keyword in the title: *Here: the natural state of Alberta*, *Now: an accumulation of the past*, *Look: the record of change in Alberta*, and *See: effects of a changing climate*. Video and still imagery are incorporated into the visualizations with the intent of creating greater significance of the data for the audience. This series utilizes ancillary data (see Appendix C) to provide additional information to contextualize the data.

Here: the natural state of Alberta



Fig 15: Still from *Here: The Natural State of Alberta*

The first visualization in this series focuses on building a foundational knowledge of the natural features in Alberta. Working from the text *Natural Regions and Subregions of Alberta* (2006) by the Natural Regions Committee, I charted eight key features for each of the six natural regions and the twenty-one subregions. This included their size, mean temperature in the warmest month, mean temperature in the coldest month, vegetation, terrain, wetlands and open water, land uses, as well as a feature distinctive to that area. These features were chosen based on the background information that is needed to better understand the environmental impacts of climate change, which is displayed in the fourth visualization in this series. Each feature was then graphically coded as rings around the title of the region to create twenty-one unique mandalas (Fig 15). The graphic coding for each ring reflects the data it represents: precipitation, temperature, vegetation, and physiography, details for which can be seen in Fig 16. The precipitation ring is encoded as

raindrops, each representing 5mm. The display of quantity references the method of measuring precipitation, in bucket-like devices at the climate stations. The temperature ring references the design of thermometers, where 0 is in the middle and positive temperatures are above, and negative temperatures below. The vegetation ring displays the main vegetation types for each area as illustrations. Given that specific tree and grass types are not common knowledge, having the visual reference was critical to linking the information to what it represents. Finally the physiography of the landscape is a simple reference to the description of the land given by the reference author, as well as the elevation range. The rotation of the two suggests the diversity of the landscape within this range, rather than a static uniformity.



Fig 16: Detail from *Here: The Natural State of Alberta*.

For example, the outermost ring in figure 12 is representative of the sloping lower foothills with an elevation ranging from 1025-1525 meters above sea level (Natural Regions Committee, 43). Each mandala is associated with a landscape image from its area to provide

additional visual information and work as a reference point for some of the features (like open water in Fig 15). In some cases additional data specific to the photograph is visualized and appended with the mandalas.

Now: an accumulation of the past



Fig 17: Still from *Now: an accumulation of the past* showing sixty years in comparison to the earliest evidence of humans in Alberta.

“The past is not dead, it is living in us, and will be alive in the future which we are now helping to make.” (William Morris)

This visualization focuses on providing context and suggesting significance for the quantity of time that the climate data represents (Fig 17). Since the experience of time is relative to our own observations, a narrative was created comparing the duration of sixty years to the history of human experience in Alberta, from the first evidence of human activity 14,014 years ago, to the first known European 260 years ago, to the current average Canadian lifespan of 80 years.

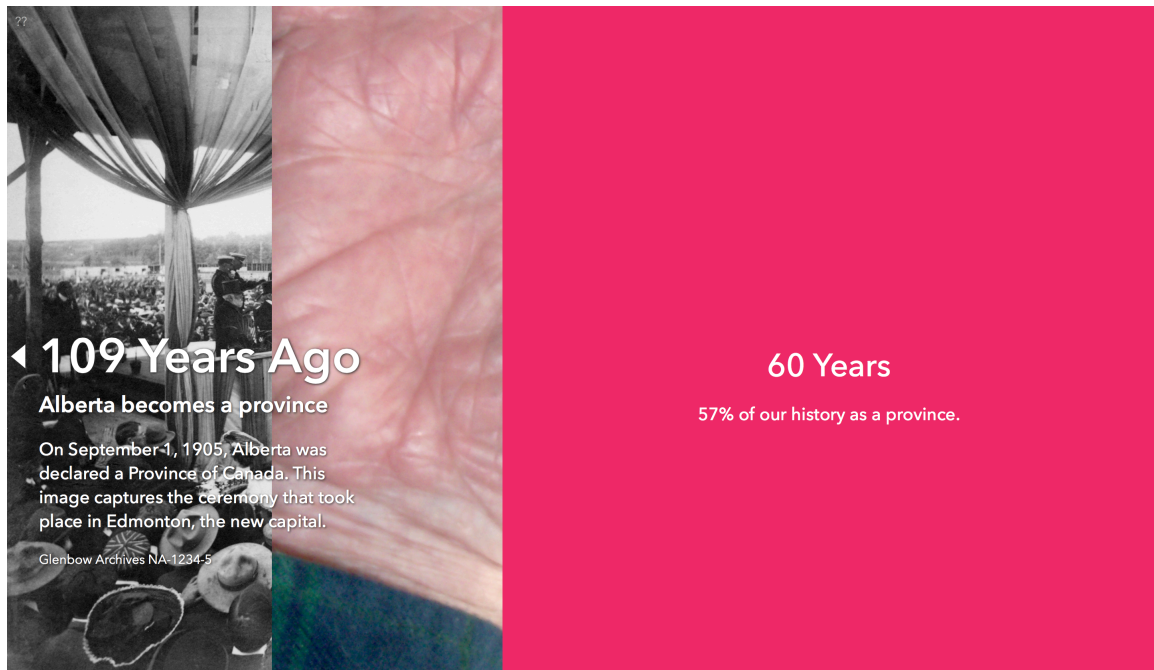


Fig 18: Still from *Now: an accumulation of the past* showing sixty years in comparison to when Alberta became a province

The design concept went through several iterations and arrived at this one due to how the data (the different periods of time) is represented as widths of images (or the pink block of colour for sixty years) that adjust with the display size. The widths of each section have been mathematically determined so that sixty years shifts in proportion to where you are in the timeline. Incorporating transitions became particularly important in maintaining the users orientation while also maximizing the width of the display as the total length of time for each stage.

Although this visualization walks the line of objectivity the most due to its implicit reference to anthropological land use and climate change, I felt it was important to show that while 60 years might seem like a long time for change to occur, it is minute compared to our total history in the area.

Look: the record of change in Alberta



Fig 19: Still from *Look: the record of change in Alberta*

The third visualization in this series is the first opportunity for the audience to *look* at the climate data itself. Viewed in the order I've intended, the audience enters this visualization with an understanding of the diversity in Alberta's landscape and the time scale of the data. The visualization begins with a short introductory video explaining the data and its source. It then arrives on a map of Alberta showing the total trend changes for one of the indices, visualized as colour values for each 10km² location across Alberta (pictured above is growing season, Fig 19).

The design of this piece facilitates a broad overview of the trend analysis conducted by Dr. Kienzle. Each index is given a unique colour range, which was chosen based on the qualities of the data being represented (ie green for growing season, warm colors for heat waves and days over 25C, and cool colours for the cold indices). Since the colour ranges needed to show both increasing days and decreasing days, an opposite colour was required

that had the same saturation and lightness. In doing so, similar degrees of change in both directions would be represented with the same optical perception of value.

The value of total change of an index's trend corresponds to a color value on the range (Fig 20). The resulting colours are then assigned to their grid locations on a map of Alberta.

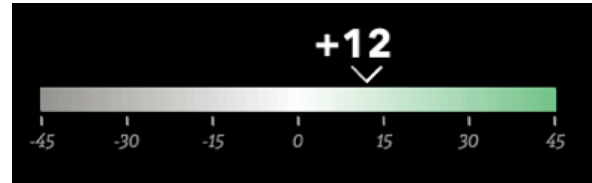


Fig 20: Detail of the colour legend from *Look: the record of change in Alberta*

As each location has different amounts of change, a mosaic is created of different values of change across the province. The relationships in the data that this visualization method is able to show include nominal comparison, deviation, and distribution as they relate to different areas of Alberta as a whole. As the user mouses over the map, the visualizations on the right update for each location. Double clicking or scrolling allows the user to zoom into the map to an area of interest, perhaps where they live or enjoy recreational activities.

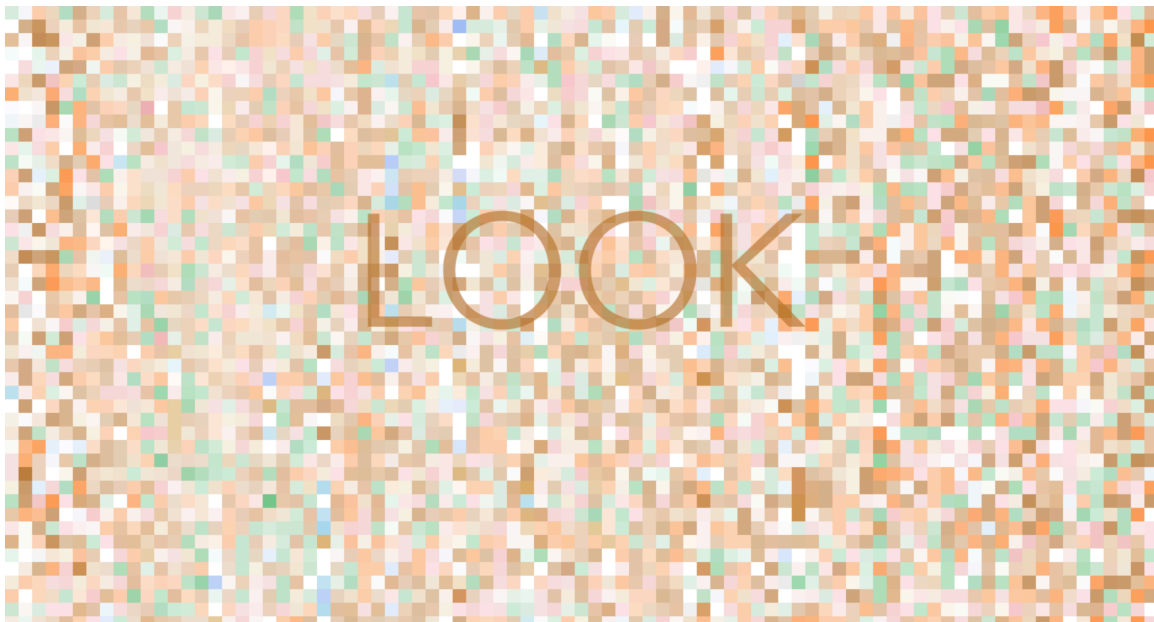


Fig 21: Still of the screensaver from *Look*

In an exhibition environment, the interactive is also designed to load a screensaver after a period of inactivity (Fig 21). The screensaver is composed of a grid of the 10km² locations cycling through their assigned colour values for each index. As the main piece does not allow you to see more than one index at a time, this gives an idea of the predominant trends based on the dominance of warm or cool values. Once the mouse is moved again, the introductory video launches, refreshing the experience in the exhibition context for a potentially new viewer.

See: effects of a changing climate

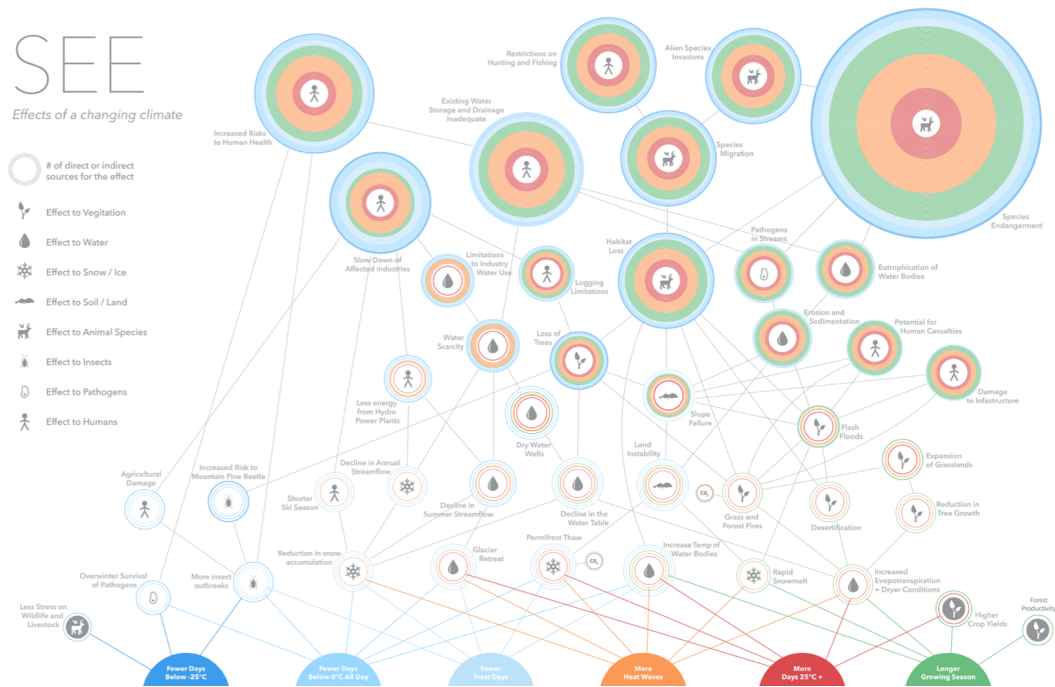


Fig 22: Still from *See: effects of a changing climate*.

The final visualization in this series extends the story of the changing climate trends to show the impacts that scientists have observed certain changes to cause. The impacts that are visualized in this interactive are based on the paper *Climate Change Impacts on Canada's Prairie Provinces: A Summary of Our State of Knowledge* (2009), which was

recommended to me by Dr. Kienzle for background research. As I read the paper, it was evident that initial effects from temperature changes set off other changes, which set off others, all compounding to impacts with multiple sources cause them. To see how the interconnectedness of the causes and effects added together, I devised a visualization method to map the network with nodes for each level of impact.

Starting with the trend changes in temperature indices, which were indicated in the paper and further supported by Dr. Kienzle's climate data (fewer frost days, more growing season days), each of the effects of these changes are given a ring of color that correlates with each of its causes. The rings compound as multiple causes contribute to each effect (Fig 24).

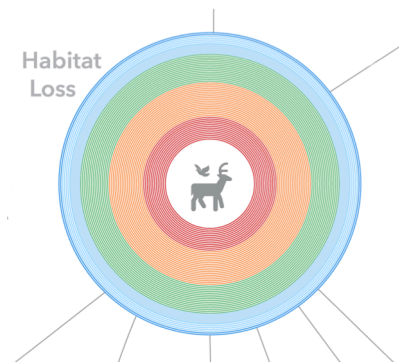


Fig 23: Detail from *See: effects of a changing climate.*

The result is a complex web that requires the audience to study the visualization closely to follow the chain of effects. I believe it is in the complexity of this graphic that that point is best made. Tools for reading the graphic are given at the side, so that they can decode the meaning of the rings and the types of effects. Reflecting on the graphical system I chose to visually represent the paper, while the links between the causes and effects were directly pulled from the paper, the compounding of the rings are my addition to illustrate the underlying network present in the information. Consultation with Stefan confirmed that this was a fair assessment and representation.

This visualization extends the story of the climate data from Dr. Kienzle with the environmental impacts observed by Canada's scientific community. It also builds on the

Exhibition: facilitating conversation on climate science

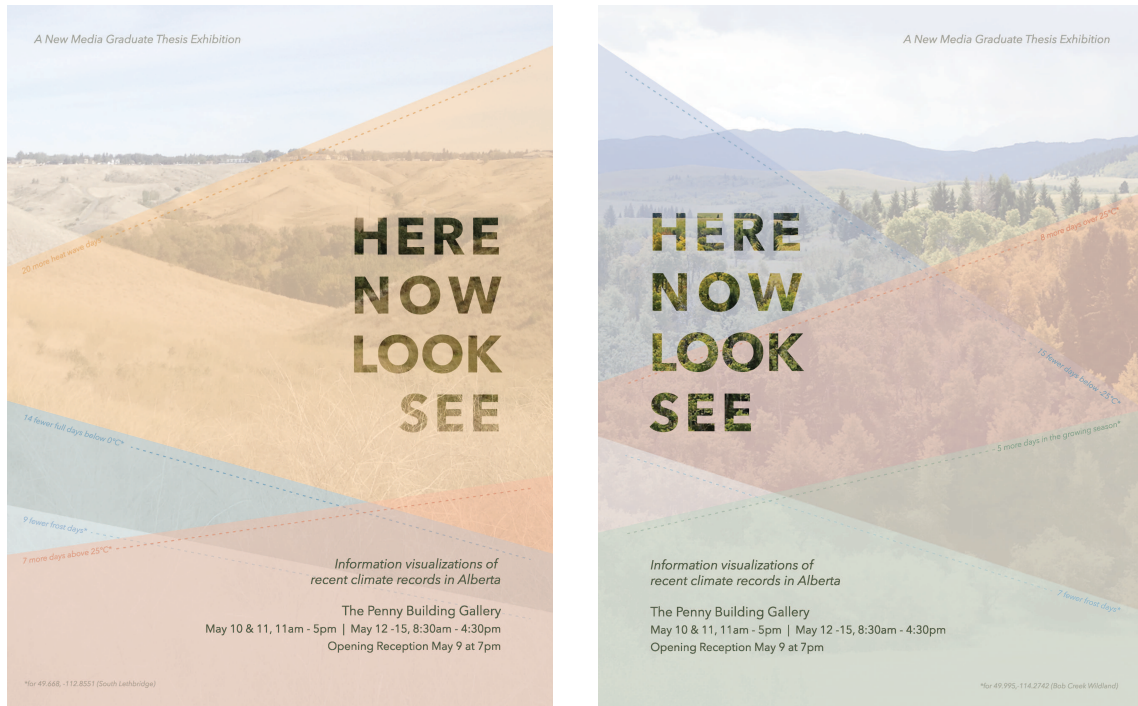


Fig 25: Posters for the exhibition of *Here / Now / Look / See* at The Penny Building Gallery in Lethbridge, Alberta

An exhibition of the work took place from May 9th to May 15th, 2014 at The Penny Building Gallery in Lethbridge, Alberta. The intention of the exhibition was to provide an opportunity for people in the area to have access to the climate data that indicates change in ‘their backyard.’

The main challenge in designing the exhibition was to maintain the narrative sequence that the visualizations are ideally viewed in. Working with the layout of the room, the four visualizations, *Here: the natural state of Alberta*, *Now: an accumulation of the past*, *Look: the record of change in Alberta*, and *See: effects of a changing climate*, were projected in a row along a large wall from left to right (Fig 26).



Fig 26: Series of four projections at the exhibition opening. Dr. Stefan Kienzle can be seen in front of *See: effects of a changing climate*, explaining a detail to onlookers. Photo by Leanne Elias.

The cumulative visualization of the climate data, *Climate Change in Alberta?* (Fig 27), was situated farthest from the entrance to increase the likelihood that attendees would be exposed to the other visualizations first, and would therefore have more background information to inform their engagement with this visualization.



Fig 27: Exhibition attendees interacting with *Climate Change in Alberta?* Second from the left, Dr. Stefan Kienzle is in conversation with other attendees. Photo by Leanne Elias.

A diverse group of people attended the opening reception of the exhibition, including members of the University of Lethbridge Faculty of Fine Arts, the Lethbridge art community, the Lethbridge scientific community, and, of course, friends and family. Also in attendance was Dr. Stefan Kienzle, whose presence had an extraordinary effect on the evening and became one of the most rewarding results of the project as it revealed another layer of purpose to the visualizations. Using the visualizations to mediate the conversation, Dr. Kienzle was able to engage with attendees at an accelerated rate, picking up from various points of the narrative to explain elements in more detail, extending the story of the data beyond what was included in the visualizations. From the common ground of understanding that the visualizations provided, the level of discourse between Dr. Kienzle and attendees became elevated, allowing for Dr. Kienzle's expertise to be called on more comprehensively. To witness this exchange as a result of my work was incredibly fulfilling. My collaborator, Dr. Kienzle, also enthusiastically echoed this sentiment.

While I am not able to accurately measure the audience's experience of the visualizations, the feedback I received has been extremely positive. Of the limited sample of exhibition attendees, each individual had their own experience and interpretation of the work, observing the data in context with their beliefs about climate change, environmental stewardship, as well as with their level of data literacy. My part in this exchange of information can only go as far as using tools and design methods to the best of my ability to create a space where a meaningful, informative, and motivating experience can take place.

Future Steps

Since the exhibition of *Here / Now / Look / See* in Lethbridge, the visualizations have been under development for a web release. Having the climate data accessible online is

critical to enable open accessibility to the climate data (for more on open data, see Appendix C). In a web format, further design considerations are necessary to create a cohesive user-experience that includes an introduction, over-arching narrative, and ability to explore all five visualizations.

In addition, the visualizations created in Processing, a java-based programming language that is not web-friendly, require their code to be translated into JavaScript. For this, a new open-source JavaScript library, P5.js, has recently been released that is specifically based on Processing, opening up the popular program to be developed and experienced online. The library's website, p5js.org, is a rich resource of examples and tutorials for a growing community of coders. Ideally, my visualization projects would have been coded in a web-friendly language from the start. However, for the available visualization tools at that time, Processing was best suited to the project's objectives and my own technical skills. Luckily, now that P5 has been released, translating the code will be a fairly smooth transition. As Marshall McLuhan said in his 1967 book, *The Medium is the Message*: "Our Age of Anxiety is, in great part, the result of trying to do today's jobs with yesterday's tools!"

Set to launch in October 2014, herenowlooksee.com will host the online version of the *Here / Now / Look / See* project, providing open access of the climate data to all Albertans and the online community at large.

Conclusion

The research presented in this paper describes the theoretic and methodological rationale that informed my practice of creating information visualizations of climate data. The studio work followed a line of investigation into the ways that design methodologies can be applied to the practice of information visualization in order to mitigate the challenges of data literacy, information apathy, and bias when communicating information on wicked problems.

Through the practice of visualizing the climate data it became evident that methodologies addressing one of the identified challenges (data literacy, information apathy, or bias), can sometimes compromise the others, leading me to question: *is it possible to address all three challenges together?* In the spectrums that emerge from attempting to address all three, balance seems to be the means to do so (Fig 28).

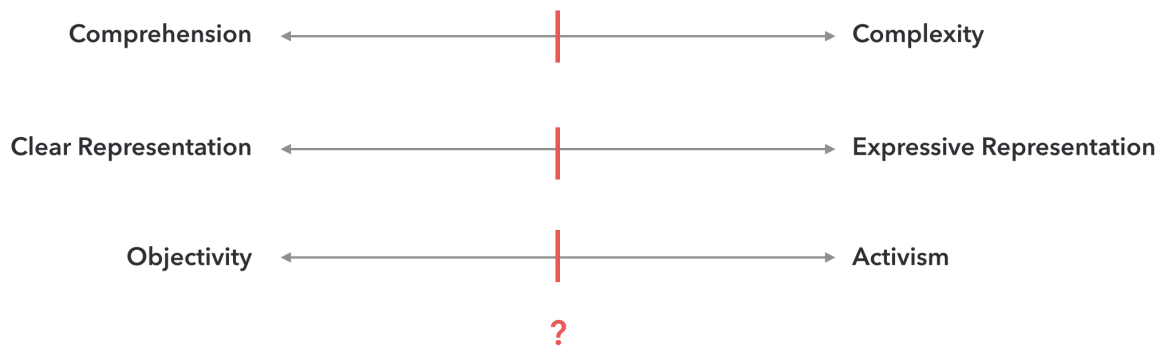


Fig 28: Spectrums that emerge when addressing data literacy, information apathy, and bias in information visualization of wicked problems.

For data literacy, designers seek to find an optimal degree of comprehension and complexity for their target audience. For incorporating visuals and context to address information apathy, there needs to be a balance between clarity and expressive representation. For bias, there is a clear question of maintaining objectivity while having

the audience arrive at the desired conclusions. Through the design process of *Here / Now / Look / See*, I found that also searching for the optimal balance of explanation and exploration, function and aesthetic became key points of reference for maintaining peaceful coexistence between the three challenges, asking questions throughout, like: *Where can the user explore and when is it important to control the delivery of information to insure they understand the data when they see it? Does the inclusion of photographic references support the functionality and communication of the data or does it distract? And To what degree does including contextual reference suggest author bias?*

Based this experience, I maintain that data literacy, information apathy, and bias are critical to consider in the design process of information visualizations on wicked problems. While the success of the project can only be determined by the experience of each individual within their own set of perceptions and beliefs, at the very least it allows Dr. Kienzle's data to be comprehensively accessible to the public.

The information visualization community is working tirelessly at being reliable ambassadors of information, recognizing the responsibility of this role in communicating important datasets that are being made available. My hope is that my work contributes to this discourse and is a window to the carefully calculated design process of representing data of complex and socially significant topics such as climate change.

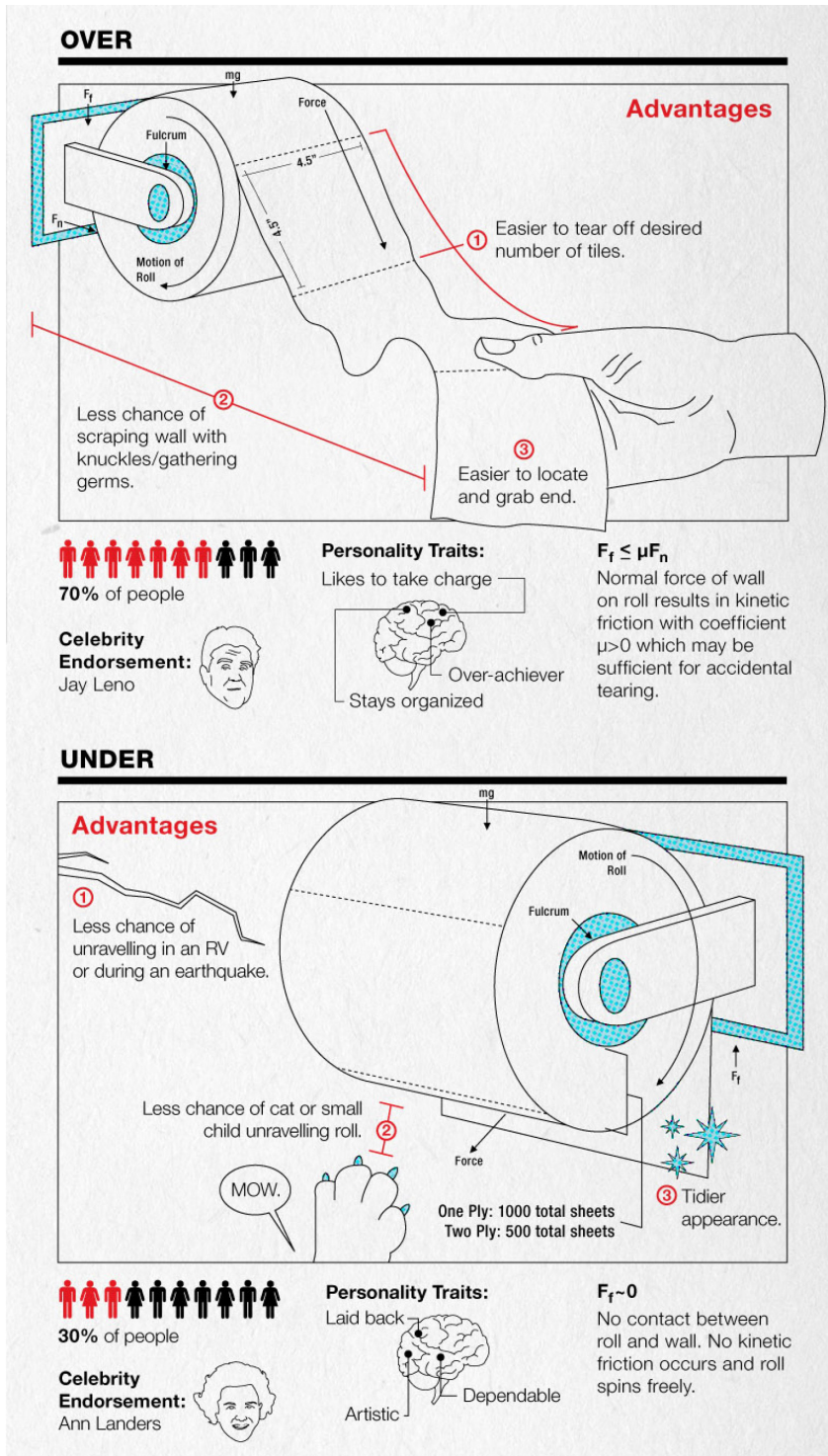
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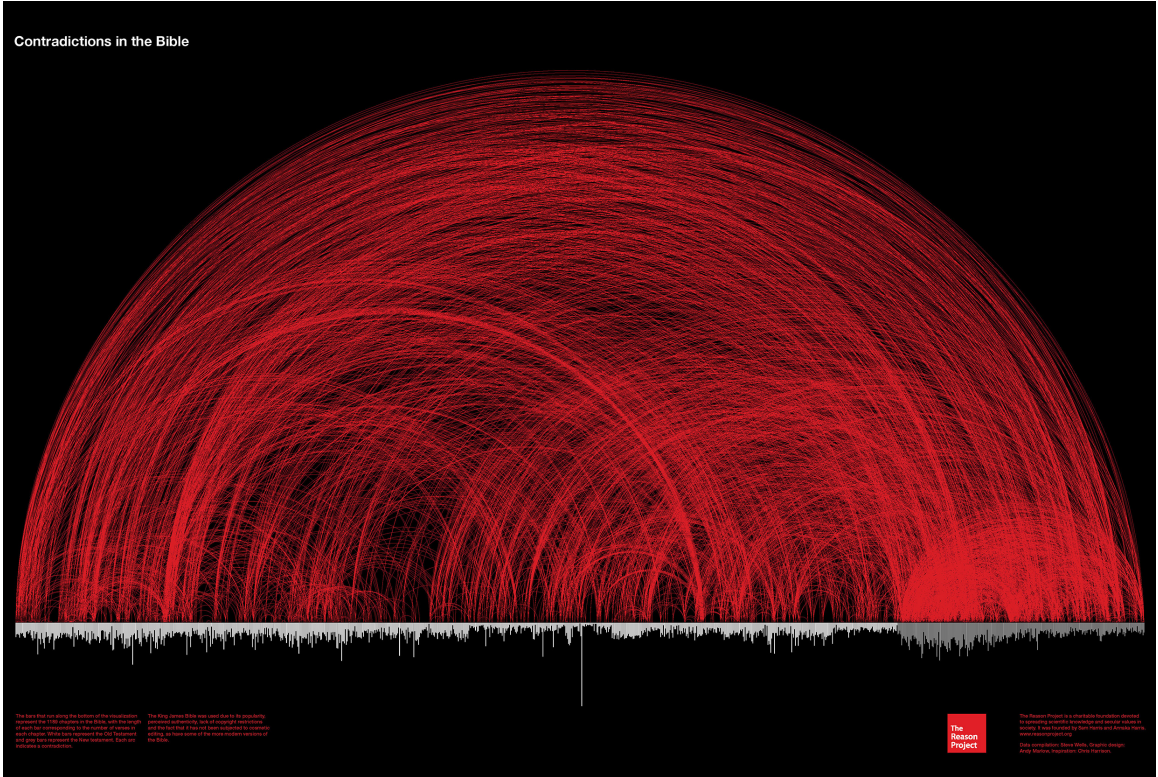
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Appendix A: Infographics



"Over or Under: The Great Toilet Paper Debate" (2013) by Bobby Bernethy. From Visual.ly.com



Contradictions in the Bible (2009) by Andy Marlow and Chris Harrison. From Project-reason.org.

Appendix B: The Data

Dr. Stefan W. Kienzle, Associate Professor of Hydrology and GIS at the University of Lethbridge, describes the climate data used in my thesis project:

The National Land and Water Information Service (NLWIS), part of Agriculture and Agri-Food Canada (AAFC), released the daily 10km gridded climate dataset for Canada for the period 1961-2003.⁷ The dataset consists of 10 by 10km grids cells for daily minimum and maximum temperature (Tmin, Tmax) and precipitation (P) for the Canadian landmass south of 60° N. Grid values were interpolated from daily climate station recordings (Environment Canada) using a thin plate smoothing spline surface fitting method.⁸ In comparison with other interpolation techniques, this method performs well when interpolating noisy climate data across complex terrain.

The daily climate grids were recently extended to cover the period 1950 - 2010, and have been made available to Dr. Kienzle for his impacts on climate change research. This extended dataset is currently not publically available.

⁷ AAFC (Agriculture and Agri-Food Canada). 2008a. Gridded Climate Data, <http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1227620138144&lang=eng> link does not work anymore.

⁸ Hutchinson, M.F., D.W. McKenney, K. Lawrence, J.H. Pedlar, R.F. Hopkinson, E. Milewska, and P. Papadopol, 2009: Development and testing of Canada-wide interpolated spatial models of daily minimum/maximum temperature and precipitation 1961-2003. *J. Appl. Meteorol. and Climatol.*, 48, 725-741.

Appendix C: Ancillary Data

Throughout the development of my research project, numerous ancillary data sets depicting various features of Alberta were acquired from websites known as open data portals. In many cases, these open data portals provided questionable or outdated information, frustrating users and defeating their mandate of transparency. The open data movement seeks to break down information barriers between information bodies like government, corporations, and research institutes, and the general public. OpenDefinition.org defines open data as “data that can be freely used, reused and redistributed by anyone – subject only, at most, to the requirement to attribute and sharealike.” According to the organization, open data must also be distributed as a whole in an easily accessible and modifiable form, the availability of which does not discriminate against fields of endeavor or against persons or groups (e.g. non-commercial or educational restrictions).⁹ However, even when conditions of access to data have been met, a final barrier for many is the ability to *comprehend* the data. Without intermediary analysis, raw data it is of little use to the average person, obscuring any insights to be gained from the data and essentially eradicating its ‘openness’.

The need for an intermediary with the purpose of distributing data in a format that is both highly detailed and comprehensible is what has led information visualization to play a

⁹ "The Open Definition Version 1.1." *Open Definition*. Open Knowledge Foundation, 2011. Web. 26 June 2013. <http://opendefinition.org/okd/>

key role in the open data movement. It can be used to present data with multiple levels of detail in an interactive format that allows for in depth analysis while also being digestible for non-technical audiences (keeping in mind the open data movement's mandate for indiscriminatory access). In doing so information visualization can break down the final information barrier of comprehension and the data can truly be considered open.

Acknowledgement of the importance of working towards open data continues to grow, most recently made apparent by the signing of the G8 Open Data Charter at the 2013 G8 conference. The Charter recognizes that "while governments and businesses collect a wide range of data, they do not always share these data in ways that are easily discoverable, useable, or understandable by the public" and that failing to do so is "a missed opportunity." It further commits the G8 governments to follow a set of principles in relation to accessibility of data, one of which promises to increase open data literacy and encourage developers to "unlock the value of open data."¹⁰ This seems to acknowledge the need for intermediaries to give tangible value to the data they provide, but that they will not be taking on this responsibility. Regardless, as more data becomes available, opportunities for information visualization will follow, although it remains to be seen how these points are interpreted and implemented by each government.

¹⁰ Canada. Foreign Affairs, Trade, and Development Canada. *G8 Open Data Charter*. Government of Canada, 19 June 2013. Web. 25 June 2013. <http://www.international.gc.ca/g8/open_data-donnees_ouvertes.aspx?lang=eng>.