Visualization Rhetoric: Framing Effects in Narrative Visualization

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Abstract— Narrative visualizations combine conventions of communicative and exploratory information visualization to convey an intended story. We demonstrate *visualization rhetoric* as an analytical framework for understanding how design techniques that prioritize particular interpretations in visualizations that "tell a story" can significantly affect end-user interpretation. We draw a parallel between narrative visualization interpretation and evidence from framing studies in political messaging, decision-making, and literary studies. Devices for understanding the rhetorical nature of narrative information visualizations are presented, informed by the rigorous application of concepts from critical theory, semiotics, journalism, and political theory. We draw attention to how design tactics represent additions or omissions of information at various levels—the data, visual representation, textual annotations, and interactivity—and how visualizations denote and connote phenomena with reference to unstated viewing conventions and codes. Classes of rhetorical techniques identified via a systematic analysis of recent narrative visualizations are presented, and characterized according to their rhetorical contribution to the visualization. We describe how designers and researchers can benefit from the potentially positive aspects of visualization rhetoric in designing engaging, layered narrative visualizations and how our framework can shed light on how a visualization design prioritizes specific interpretations. We identify areas where future inquiry into visualization rhetoric can improve understanding of visualization interpretation.

Index Terms—Rhetoric, narrative visualization, framing effects, semiotics, denotation, connotation.

1 Introduction

Narrative information visualizations are a style of visualization that often explores the interplay between aspects of both explorative and communicative visualization [38]. They typically rely on a combination of persuasive, rhetorical techniques to convey an intended story to users as well as exploratory, dialectic strategies aimed at providing the user with control over the insights she gains from interaction. Segel and Heer take an initial step towards highlighting how varying degrees of authorial intention and user interaction are achieved by general design components in narrative visualization [38]. This blend of explorative and communicative features presents another research opportunity though: to better understand a user's interpretation process of a narrative visualization in light of the rhetorical conventions that the author employs. By *explicating rhetorical techniques and how such techniques may affect user interpretation*, researchers and designers alike stand to gain a tool for understanding how visualizations communicate.

In this work we examine the design and end-user interpretation of narrative visualizations in order to deepen understanding of how common design techniques represent rhetorical strategies that make certain interpretations more probable. How are rhetorical techniques used in visualization and what are the effects of these techniques on user interpretations of data? Studies in semiotics, journalism, and critical theory indicate particular rhetorical techniques used to communicate an intended message [1, 2, 23]. while evidence from decision theory, survey design, and political theory [21, 36, 37] suggests that subtle variations in a representation's rhetorical or persuasive techniques can generate large effects on users' interpretations of a message. Investigations related to InfoVis provide initial evidence that how data is framed or presented can significantly affect interpretation [3].

Given the motivation to better understand the interpretation process of visualization, this paper investigates rhetorical strategies and effects in narrative visualization by addressing the following research questions:

- What particular conventions are used, and to what extent are specific techniques associated with different editorial layers in the visualization (such as the data, visual representation, annotation, and interactivity)?
- In what ways can factors external to the visualization itself, such as internalized knowledge and conventions at the individual and community level, interact with the rhetorical strategies used in a narrative visualization to influence interpretation?
- How do communicative and explorative rhetorical strategies effectively work together in a narrative visualization?

This work contributes to InfoVis design and theory by providing insight into (1) the types and forms of use of particular rhetorical techniques in narrative visualizations, and (2) the interaction between those techniques and individual and community characteristics of end-users. The first contribution is a taxonomy of how particular design elements can be used strategically to directly or indirectly prioritize certain interpretations. This equips designers with a set of techniques for designing engaging narrative visualizations capable of communicating layered meanings. At the same time, the identification of classes of rhetorical techniques provides both designers and InfoVis researchers with a vocabulary for analyzing the underlying rhetorical functions of particular design strategies, a dimension that remains under-discussed in many theoretical frameworks organized primarily around exploratory visualization.

The second contribution of this work is in identifying and demonstrating how these conventions interact with characteristics of the visualization interaction, end-user's knowledge, and the socio-cultural context. This stands to improve designers' awareness of how designs might be received differently by individual end-users and how they can cue shared cultural knowledge and associations. These "extra-representational" factors also tend to be neglected when designing or analyzing visualizations based on design principles such as those proposed by Tufte [45]. Researchers in InfoVis can benefit from a holistic understanding of visualization interpretation capable of providing insight into how particular interpretations arise as a result of interactions between a visualization, user mental models, and other external representations. This view is congruent with a distributed cognition model of InfoVis [26].

This paper is organized as follows: Section 2 defines important terms related to rhetoric and contextualizes these concepts in InfoVis as well as semiotics, decision science, and political theory. We also describe our work in the context of research on narrative

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visualization. Section 3 outlines many specific visualization rhetoric techniques based on a systematic qualitative analysis of narrative visualizations, and describes how these techniques form clusters of strategies exemplifying different rhetorical operations. Analytical devices for understanding the site of techniques and their interaction with end-user characteristics are also presented. Section 4 uses two case studies to demonstrate how an understanding of visualization rhetoric can provide insight for the analysis and design of narrative visualizations. Section 5 discusses themes emerging from our analyses and highlights areas for future study.

2 Bias and Rhetoric in Communication

In this section we address the terminology used in the paper and define visualization rhetoric. We then motivate the importance of our work and contextualize it with that of other relevant fields. This draws attention to the need for deeper understanding of visualization interpretation as it relates to rhetorical techniques and design.

2.1 A Note on Nomenclature

This paper's focus on visualization rhetoric stands at the intersection of ideas of *bias* and user-designer relationships as understood in InfoVis, on the one hand, and theories of *rhetoric, framing* and author-reader interactions as elaborated in critical semiotic theories for literature, political rhetoric, and media artifacts on the other. *Bias*, *rhetoric, framing* (and the related literary term *perspective*) all describe how an interpretation arises from the interaction of representational, individual, and social forces. Differences can be traced mostly to superficial differences adhering in ordinary language. *Bias* is often defined in negatively connoted terms: "a systematic error introduced into sampling or testing by selecting or encouraging one outcome or answer over others" [Merriam-Webster]. To *frame* an idea is typically more neutrally defined as to "form or articulate" [Oxford American] or "shape, construct" [Merriam-Webster]. Similarly, the concept of perspective tends to be either neutrally or positively-connoted in literary and critical theory as a productive force in the telling of a story. The term *rhetoric* has a complex history, but has come to be associated with persuasion as a result of the implicit motivation of the speaker to gain other adherents to a preconceived view or conclusion [7].

We use the term rhetoric to refer to the set of processes by which intended meanings are represented in the visualization via a designer's choices and then shaped by individual end-user characteristics, contextual factors involving societal or cultural codes, and the end-user's interaction. While this term may bring to mind negatively connoted notions of persuasion as bias common in some InfoVis literature, we seek to objectively describe the rhetorical nature of visualization design rather than to comment on the appropriateness of persuasion in visualization design.

2.2 Information Visualization

Despite its parallel meaning to terms like *rhetoric*, the pejorative term *bias* is more often found in InfoVis literature. Early theory emphasizes the analytic nature of graphical displays (e.g. [8]), as well as automated methods that optimize constraints imposed by human perceptual and cognitive abilities (e.g. [27]). Unequivocal designs are prioritized; "in the ideal case a chart or graph will be absolutely unambiguous, with its intended interpretation being transparent" ([22], pg. 192). Immediate clarity and minimal intervention on the part of the creator are emphasized [45]. Where editorial choices must be made, designers are urged to provide detailed provenance information like the objective, time, and location of graph creation [44].

Some recent InfoVis work has striven to overcome the narrow focus on optimizing visualization clarity and efficiency that dominated earlier work, acknowledging that interacting with a visualization involves thinking about and being influenced by factors beyond just the visual representation. Evaluation models like [30] explicitly acknowledge that risks to validity can enter at levels beyond the visual encoding and interaction design, such as in characterizing the domain tasks and data. Additionally, several studies demonstrate that extra-representational preferences and conventions can influence interpretation, such as when the visual format cues interpretation frames [3] or individual differences lead to differing visualization usage [56]. As Norman [32] describes, interpretations can be unpredictable when design elements may not immediately communicate the designer's intended meaning as a result of influences on interpretation deriving from the end-user's context. Liu and Stasko [26] frame the site of such differences via the mental model concept, arguing that the effects of such differences on interpretation have been underexplored in InfoVis. This supports a call for further consideration of visualization's role within webs of situated representations.

The visualization rhetoric model we propose is likewise motivated by an expanded view of visualization that takes into consideration under-acknowledged facets of design and interpretation. For instance, creating a visual representation necessitates simplification, as data is used to create an analytical abstraction that is transformed to a visual representation [55]. Thus a rhetorical dimension is present in any design. Secondly, a designer's intentions may remain implicit and inarticulable by him or her, making it impossible to comply with the principle of providing full provenance. From the end-user's perspective, the pleasure of a concise, visual representation may be decreased if engaging with the visualization also requires sifting through explicit description of every design manipulation.

2.3 Framing in Decision and Opinion Formation

Empirical studies in decision theory and political messaging provide additional evidence that even subtle changes in the rhetorical frame of an information presentation can significantly influence responses. In contrast to the mostly aloof posture towards intentional use of rhetorical devices in InfoVis literature, psychological, political and communication theorists have developed framing theory to investigate opinion formation processes in light of how people orient their thinking about an issue. Typically, these processes are viewed as responses to the use of particular communicative structures in messaging (e.g., [12, 21, 46]). Researchers seek to better understand "framing effects", situations where often small changes in the presentation of an issue or an event, such as slight modifications of phrasing, produce measurable changes of opinion [35]. Information representations can influence interpretation in diverse ways, such as by presenting a preliminary statistic before a decision [ibid], or by manipulating the anchor points on a survey scale [37]. Of particular relevance to InfoVis are findings that are explicitly visually-based. For example, the amount of space provided between response choices in a scale can be interpreted as reflecting the underlying dimension and lead to different results when manipulated [43]. This literature further motivates a need to articulate and understand the implications of rhetorical strategies in visualization.

2.4 Semiotics

Semiotics describes literary, visual, political, and other critical studies that examine how representations like texts, paintings, iconography, or media messaging can be decomposed into systems of signs. Signs—(defined as any material thing that stands for a non-present meaning, such as a word, color choice, or visual icon)—become meaningful through their interaction with other signs within a representation, as well as with signs that are culturally present (e.g., [2]). Semiotic theory has been introduced in HCI as an inspection method for interactive interfaces to help assess the designer-user meta-communication via the interactive artifact [17]. First applied by Jacques Bertin [4] as a tool for describing how information visualizations convey meaning, semiotic theories emphasize the communicative properties of visualizations alluded to in recent works [48]. This can serve designers seeking to better convey their intended messages [1] and increase their awareness of how design

choices may affect interpretation. Semiotic theorists analyze the relationships between forms of media, their production, and the "modes of seeing" or interpretive conventions that they engender. The concept of viewing codes, including visual, textual, cultural, and perceptual [10], describes the implicit, often internalized standards that support interpreting an artifact in a certain way. This motivates incorporating extra-representational factors like individual and group conventions into a visualization rhetoric framework.

2.5 Narrative Visualization

In response to the growing number of online visualizations designed to convey a story, Segel and Heer's [38] design space analysis presents three ways of distinguishing categories of narrative visualizations: (1) genres; (2) visual narrative tactics that direct attention, guide view transitions, and orient the user; and (3) narrative structure tactics such as ordering, interactivity, and messaging. Their contribution of abstract structures and genres provides a general framework that opens the discussion of narrative visualization to a wider range of examples. The framework also allows comparisons between visualizations based on how they structure users' interactions with data. We aim to expand the discussion of narrative visualizations to include the role of extra-representational influencers like individual, group, and contextual differences in interpretation. We outline additional visual and non-visual tactics used in narrative visualization, emphasizing how these represent omissions, additions, and implications.

Ziemkiewicz and Kosara [55] contrast information visualization with visual representations. Narrative visualizations tend to be excluded from their model by criteria like non-trivial interactivity (allowing users to change the visual mapping parameters themselves) or non one-to-one mappings between the source domain and the visual output domain. In contrast, our work explores the dynamics of constrained interactivity and techniques like visual redundancy that are used to emphasize an intended meaning in narrative visualization. We also extend their discussion of information loss by considering the rhetorical effects of information omissions regardless of intention, based on our belief that the increased presence of such visualizations makes it important for InfoVis researchers and practitioners to better understand how the editorial process of visualizing data necessarily constrains possible interpretations.

3 Visualization Rhetoric Framework

A primary contribution of this paper is the development and demonstration of an analytical framework to guide discussion of the rhetorical aspects of InfoVis. In this section we present conceptual devices as well as the results of a large qualitative analysis used to identify specific rhetorical strategies used in InfoVis. We begin by describing the *editorial layers* of a visualization presentation where rhetorical choices are made, then describe the particular *visualization rhetoric techniques* identified in our analysis. A discussion of *viewing codes* follows, including aspects of *denotation* and *connotation,* which helps capture the role of end-users' implicit beliefs and knowledge in visualization interpretation.

3.1 Editorial Layers

Editorial judgments, and thus rhetorical techniques, can enter into the construction of narrative visualizations from multiple paths. We distinguish between four **editorial layers** that can be used to convey meaning, including the data, visual representation, textual annotations, and interactivity. A given rhetorical technique might be applied to some layers more easily than others. Yet omissions, emphases, and ambiguity can be accomplished at each level. As the output of a designer's decision processes, a narrative visualization represents a sequence of choices to either add information (such as by adding suggestions of an intended message using textual annotations) or omit information (such as by omitting some variables or interactivity features). Distinguishing the possible sites of these choices paves the way for more recognition of their existence, and effects on end-user interpretations.

At the lowest level of the **data**, the creator of a visualization makes choices about the data source to represent, including what variables to include and which to leave out. Additional choices can further affect data, such as removing outliers, scaling, or aggregating values. Both of these particular data choices lead to loss of information in the final representation, yet are necessary choices in the act of visualization design (see 3.2.2 below). The **visual representation** layer carries traces of choices made about how the data will be mapped to the visual domain. Often, this mapping is lossy as a result of human visual perception abilities. For example, mapping a continuous variable to a gray scale leads to "lost" information due to human perception's sensitivity and capability to distinguish different intensity levels (e.g., "just noticeable differences"). **Annotations** can be textual, graphical, or social, as in the inclusion of user comments in the overall presentation. Annotations have often been overlooked in InfoVis evaluation, yet serve an important role in many presentations that include visualization by focusing a user's attention on specific areas in a graph. Finally, the **interactivity** of the visualization can be the site of choices that constrain a user's interaction in ways that lead her to explore certain subsets of data. This can occur through navigation menus that limit the number of views of the data set that are possible, or linked search suggestions that likewise encourage the user to explore particular views over others. .

3.2 Visualization Rhetoric Techniques

We describe and present findings on the rhetorical strategies we observed in an extensive analysis of online narrative visualizations.

3.2.1 Method

We gathered a sample of fifty-one professionally-produced narrative visualizations, many from international news outlets like the New York Times (NYT) or BBC. In the interest of diversity we also included online visualizations from news magazines (e.g. The Economist); local news providers (e.g. annarbor.com.); political outlets (e.g. Obama.org, website of the speaker of the house); and independent graphic designers known to publish their work in leading news outlets (e.g. David McCandless). Prior to coding, we familiarized ourselves with framing or bias techniques identified in semiotics (e.g., [2, 4, 10, 17]), statistical presentation (e.g., [20, 45]). decision theory (e.g., [12, 21, 46]) and media and communication studies (e.g., [31]). We iteratively coded particular techniques we observed referring to this set of theories as a guide, and relied on general knowledge of current events and how to interpret various graph formats as needed. We restricted our analysis to the details present in the visualization and their surrounding presentation. The saliency and primacy of the observed techniques were considered as the examples were coded. As coding progressed, we noted where techniques appeared to represent different implementations of the same basic function (e.g. thresholding data by removing values above or below predefined points). In such cases we labelled these "families" of similar techniques based on their simplest shared trait. The output of this analysis was a list of visualizations coded for each technique that appeared.

Affinity diagramming was then used to arrive at higher-level clusters of techniques. As in the case of creating families of low-level techniques, we decided against a formal, mutually-exclusive scheme in favor of groupings based on similarities in the underlying mechanism. This strategy was chosen primarily because it yielded four distinguishable categories that we felt best covered our critical observations: information access rhetoric functioning to limit the amount of information presented, provenance rhetoric functioning to provide background information, mapping rhetoric functioning to map elements of the visualization to non-explicit concepts, and procedural rhetoric functioning to constrain interaction over time (Sections 3.2.2-3.2.4 and 3.2.6). One remaining cluster of techniques

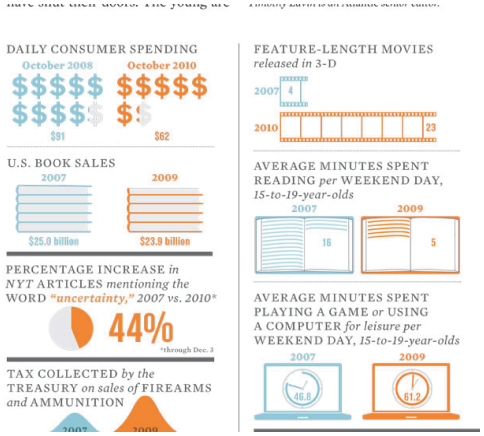


Fig. 1. 'How the Recession Changed Us' (excerpt) by Lavin of *The Atlantic* [25].

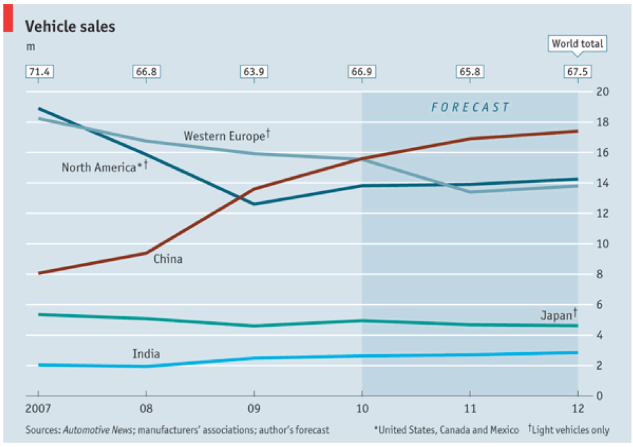


Fig. 2. 'Vehicle Sales' by *The Economist* Daily Chart column [47].

was not clearly distinguishable based on a common mechanism, but was rather comprised of methods that instead appeared to cluster based on an origin in linguistic rhetoric (3.2.5). We then tabulated patterns of frequency and co-occurrence of techniques in order to show the interrelatedness of the categories (Section 3.2.7). Alternative schemes of rhetorical techniques may be possible for narrative visualizations. However, the representativeness of our sample leads us to believe that the categories below can serve as a guide for designers seeking to strengthen or subdue rhetorical effects.

3.2.2 Information Access Rhetoric

The first decisions made by a visualization designer often concern what data to represent. To simplify complex ideas in a visual representation it is often helpful to keep distracting or irrelevant information to a minimum (e.g. [28]). **Omission** techniques are the least likely to be explicitly indicated by a visualization, yet can be inferred from data that are available given ample contextual information. Assuming that most professional producers of online visualizations are aware of the importance of data provenance, *neglecting to cite data sources* or other important provenance information or *defining variables ambiguously* can be considered omissions. These may be motivated by *knowledge assumptions* of the end-user, such as when a complex statement is made without explicit reference to intermediate clauses. In *The Atlantic's* 'How the Recession Changed Us' (Fig. 1), the overall message about negative effects of the recession assumes that end-users intuit several non-explicit propositions in decoding the iconography and statistics. The number of times that the word 'uncertainty' appeared in the New York Times, for example, only makes sense in the graphic if one assumes that mentions of uncertainty in articles equates to economic-related risks and recession. Omissions may also result from a desire to simplify complex phenomena by excluding complicating information from the visual representation, as in the case of *thresholding values* or *omitting exceptional cases*. A visual representation occurs in *axis thresholding*, in which the values most important to communicate a pattern through comparison are used to set the range of the axis, so that higher or lower values that may be relevant but complicate the message are not shown.

Omission or information loss choices can also be transferred to the end-user via *filtering* capabilities like search bars that allow a user to select a subset of data. Intentional information loss has been discussed on the part of the designer [45, 55], but has been underexplored from the perspective of user-driven filtering. The increasing prevalence of narrative visualization suggests that user-driven information loss or avoidance may be a fruitful area for research.

Metonymy techniques that manipulate part-whole relationships serve simplification as well. At the basest level, the *selection of variables* to visualize involves creating a subset of a larger data set to present a simplified visual representation of chosen features. *Averaging* techniques like mean, median, and clustering similarly substitute simpler representations for a wider range of values, as do *textual and visual summaries*. *Categorizing, binning,* or *aggregating* values can be used to make an intended effect more apparent. An Economist graph on car sales [47] (Fig. 2) depicts only 'light vehicles' for some countries' data, yet all sales for other countries.

3.2.3 Provenance Rhetoric

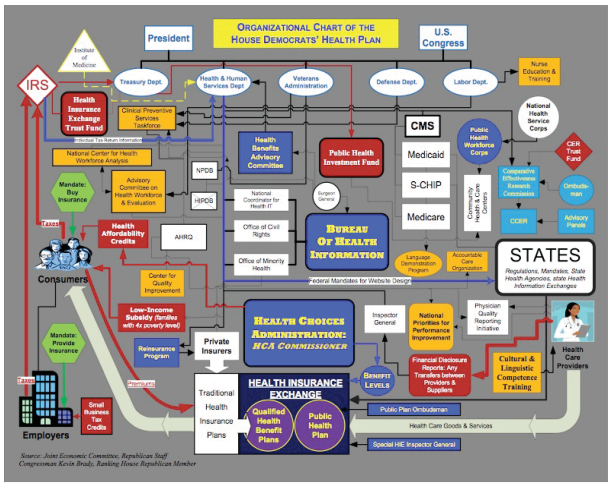
Similar to objectivity values in InfoVis, journalistic codes of ethics emphasize the journalist's duty to remain impartial and present information as clearly as possible [23]. A number of visualization rhetoric techniques observed in our sample work to signal the transparency and trustworthiness of the presentation source to end-users. Doing so conveys a respect for the audience and reaffirms a journalist's public interest motive, strengthening the journalist's credibility [ibid]. **Data provenance** strategies include *citing and/or linking data sources, additional references, methodological choices*, and *relevant facts*, as well as *annotating exceptions and corrections*, thus achieving goals proposed by Tufte for graph provenance [44]. Several of these methods are depicted in Fig. 2.

Representing uncertainty can be accomplished through visual representations like *error bars*, yet appeared more often in our sample via textual means. These included *descriptions of inferential limits* (i.e. confidence intervals), *"leap-of-faith" or forecast annotations* explicitly labelling the point in a graph where data are extrapolated, or *expressions of doubt* regarding potential conclusions (see Fig. 2, tag line below title). The dominance of textual uncertainty representations suggests an intriguing comparison between these visualizations and the visually-based ways of denoting uncertainty that have been developed in InfoVis and statistical graphics, such as error bars or confidence envelopes (e.g. [50]). The reliance on textual means may indicate a lack of adequate methods or commonly understood codes for visually representing uncertainty to non-experts [39].

Finally, in some cases explicit steps are taken to signal the **identification** of a visualization's designer. While author-designers are usually credited for their work, in some cases additional information is provided, through *author bios* or *personal anecdotes*.

3.2.4 Mapping Rhetoric

Mapping rhetoric refers to manipulating the information presentation via the data-to-visual transfer function, the constraints that determine how a piece of information will be translated to a visual feature. **Obscuring** can result from introducing "noise" into a representation, often on a perceptual level, such as in the case of adding a *gratuitous third dimension*. Other means of obscuring are applications of non-essential *sizing transformations* that violate *discriminability limits*.



Organizational Chart of the House Democrats' Health Plan

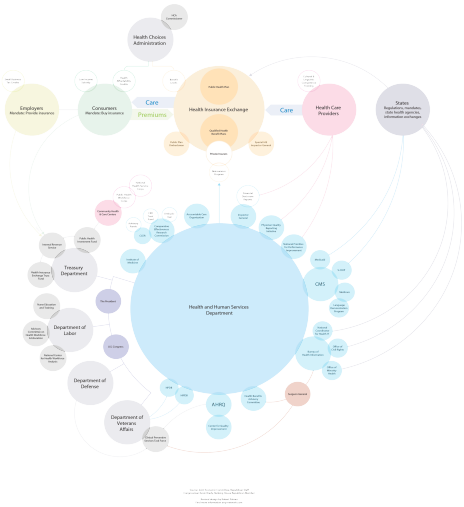


Fig. 3. Chart released on Speaker of the House John Boehner's website [33] (top); chart in response to same source's 'Organizational Chart of the Democrat's Health Plan' by graphic designer Robert Palmer [34] (bottom).

This may mean making some elements too small for judgment, *oversizing* to the point of overwhelming the presentation, or obscuring a value's true position on an axis. More subtly, non-intentional obscuring occurs when a designer *neglects to map information to the most salient visual judgment types* as suggested by work like [13]. Noise can be introduced on a semantic level, by implying *false cause-and-effect* relationships or by using complex design tactics like the *double-axis*, which experts have noted are difficult to decode even when properly used [50], (see Fig. 2 'Vehicle Sales' [47] and Fig. 7 'Poll Dancing' [29]).

Visual metaphor and metonymy maps visual signs to non-present or implicit meanings. Some of these are interpreted automatically due to congruence with embodied experience, such as *suggestive spatial mappings* like "left = past, right = future" or "up = more or better, down = less or bad" [24]. *Typographic mappings* and *color mappings* pair visualized patterns to categories via visualization components, such as by applying red and blue font colors representing political parties to statistics in an election-themed visualization [52]. *Visual noise* is a visual metaphor technique that can also serve to obscure. It has become popular in recent years through visualizations like the visually confusing graphics by political party representatives of political parties to represent the "confused" policies of the opposing group (see Fig. 3, top). Visual noise can be used more subtly as well, as in David McCandless' 'Poll Dancing' visualization [29] (Fig. 7, below) or more obviously

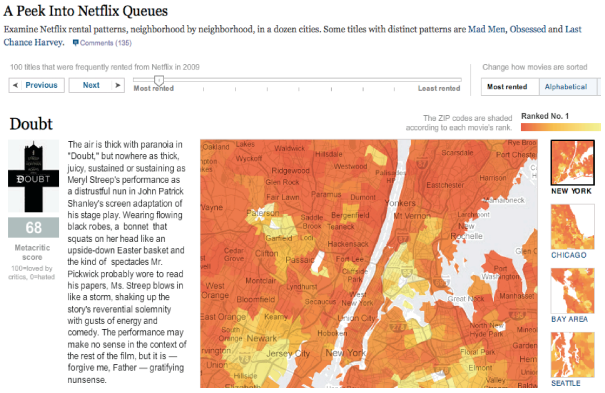


Fig. 4. 'A Peek into Netflix Queues' by Bloch et al. of the NYT [5].

as in the 'Organizational Chart of the Democrats' Health Plan' [33] (Fig. 3, top), which prompted a response graph that appeared to be motivated in part by the goal of creating a distinctly non-noisy graph [34] (Fig. 3, bottom).

Contrast techniques can serve ambiguity, as in the juxtaposition of oppositional pieces of information that occur in *visual contrasts* or *variable splices*. In these cases, information that is not obviously associated with target variables is included, adding an additional layer of perspective on an issue. An example can be found in the NYT interactive visualization entitled 'A Peek Into Netflix Queues' [5] (Fig. 4). The title and two variables of rental lists and movie rank variables are mapped to the important visual dimensions of spatial position and color. These mappings imply an overall message organized around geographic patterns in top rentals. However, a choice was made to include the less obviously relevant critic meta-scores for each movie, along with a sample NYT review of each, to the left of the map frame. The result is an implication that this information may generate further insight through comparisons with the geographic patterns. Scanning comments attached to the visualization validates that such comparisons did occur among users.

Classification can be accomplished through *grouping by size, position, or color* (see Fig. 3, bottom). *Consistent typographic manipulations* of font sizes and styles and *equations of significance* presented in a legend-like format to highlight certain values can also classify information within a visualization. Such classifications can show clusters of priority or importance.

Redundancy techniques emphasize by *disaggregating homogenous values or visual marks*. The repetition of identical labels, or the disaggregation of values with little variance or similar functions or relationships between them, can be used both to emphasize as well as to create *visual noise*. In a second politically-themed graph from John Boehner's office on a new energy tax plan [41], a label of 'Higher prices' is used repeatedly in labels placed closed to one another, presumably to emphasize the economic ramifications of the plan on taxpayers over combining the labels into one. We note that the bijective or one-to-one mapping from the data to the target (visual) domain required in Ziemkiewicz and Kosara's taxonomy for information visualization [55] is violated in nearly all occurrences of redundancy.

3.2.5 Linguistic-based Rhetoric

Multiple techniques closely resembled rhetorical devices that derive from conventions of language usage. These techniques tended to be (but were not exclusively) implemented at the textual layer, albeit with several exceptions. **Typographic emphases** like font *bolding* or *italicizing* derives meaning from conventions long associated with typography.

Irony is a basic literary and artistic strategy that sets up a discordance between the literal meanings of a statement and an alternative implied meaning. Visualizations in our sample often used *rhetorical questions* with irony, which has an effect of engaging the

user's attention by directly addressing her, while at the same time using the question in order to imply its inverse. These tend to be used in titles to sarcastically set the stage for a user to arrive at an obvious interpretation, as in 'Budget Forecasts, Compared With Reality' [16] where a prominent textual annotation above the visualization poses the question "How accurate have past White House budget forecasts been?" despite numerous other annotations explicitly describing inaccuracies in forecasts. *Quotation marks* and *deliberate understatement* accomplish similar objectives.

Similarity techniques resemble *contrast* techniques except that the comparison between two entities is motivated by assumed similarities between them. One method is *analogy,* in which a comparison is made in order to provide insight into the lesser known of two entities. *Metaphoric statements* equate two ideas or values by labelling or directly asserting that one *is* the other, as in the visualization titled 'Speaker Pelosi's National Energy Tax: A Bureaucratic Nightmare' [41]. *Parallelism* involves expressing two linguistic statements or visual features to show that they are equal in importance. An example occurs in 'How the Recession Changed Us' (Fig. 1), through the juxtaposition of infographics of roughly the same size representing different data yet each framed around negative implications of the recession. *Simile* resembles analogy and parallelism but the goal tends to be for effect and emphasis of a similarity relationship. *Double entendre* hinges on a linguistic or visual similarity alone that is used to unite two ideas or entities. David McCandless' 'Poll Dancing' visualization [29] (Fig. 7, below) uses both, in the title and vertical visual format.

Finally, **individualization** techniques represent ways to directly address or appeal to the user as an individual. These techniques are similar to directly addressing a person using a second-person tense in language. This can increase interest and ease processing on the part of the user. *Apostrophe* is the direct address of the end-user in the title and annotations attached to a visualization, including rhetorical questions and suggested goals as mentioned above. More subtle means of individualization observed in our sample include providing alternative exploratory functions like *sorting and filtering methods* (Fig. 6) and *phrasing or imagery framed from an individual-citizen level view*, such as using people icons and phrasing like 'Buy Insurance' that is framed from the ordinary citizen view in the 'Organizational Chart of the House Democrats' Health Plan' [33] (Fig. 3, top), in which labels like 'Higher Prices' that feature prominently across the top of the graph are framed sympathetic to the citizen tax-payers' perspective. Such techniques suggest that the user adopt a "Cartesian" cultural viewing code that privileges the individual (section 3.3 below).

3.2.6 Procedural Rhetoric

"Procedural rhetoric" is based in an artifact's procedural mode of representation, in other words, the expression of meanings through rule-based representations and interactive functions [7]. For instance, Diakopoulos et al. [18] use procedural rhetoric in the form of game mechanics to drive attention in an interactive information graphic. The techniques we present here are similar to Segel and Heer's [38] suggestions of interactivity features for storytelling in visualizations, yet are framed from the perspective of the editorial emphases and omissions they represent. This perspective opens them up for critical analyses of their rhetorical functions.

Anchoring techniques primarily direct a user's attention in a way that subsequently helps convey a message. *Default views* provide an initial point of interpretation anchored to the default visual configuration. *Fixed comparisons* present some information by default so that users can contrast this information with other values in the visualization. These can increase engagement via individualization when values suggested for comparisons are more likely to be salient to a user. Yet this technique also encourages a user to look for trends related to a particular data value over other potential comparisons in the larger data set. The fact that widely-known methods for judging the 'visual significance' of a trend (as one might judge statistical significance) are lacking among most users becomes a particular risk. *Spatial ordering* leverages reading and scanning conventions to prioritize some information [38]. *Animations* leverage time to suggest a story, and *partial animation* that pauses or ends on particular views prioritizes through a "climactic" effect. More subtle means of anchoring include *search suggestions* or direct or implied *goal suggestions,* prompting the user to examine particular parts of the data rather than explore freely.

More explicitly interactive techniques include **filtering**, through search bars or menuing that constrain the data depiction based on a user's preferences for certain information (this also appears in individualization, 3.2.5). Search bars are likely to be effective in engaging a user to explore data based on how the personalization of information increases the salience of the message being presented (e.g. [40]). Menu choices that appear by default can also help users find the most interesting comparisons or views in a visualization using the information gained by designers who have already thoroughly explored the data in the design process.

3.2.7 Patterns of Occurrence

While the output of our coding is indicative of the distribution of techniques found within our particular sample of narrative visualizations (i.e. many drawn from journalism outlets), a sample from other genres of visualization would likely produce a different distribution. Still, our results allowed comparisons of differences in the frequency of specific techniques, as well as co-occurrence trends. The top ten most prevalent techniques (ranked by frequency) were grouping by color, aggregating values, suggestive spatial mappings, goal suggestions, bolded fonts, data source citations, metaphoric statements, color mappings, apostrophe, and variable splices.

A conclusion to be drawn from this ranking concerns the way that many of these techniques represent common strategies in a wide variety of data visualizations, based on their perceptual salience (e.g., spatial mappings, grouping by color) or their common use in other facets of communication (e.g., metaphoric statements). The fact that standard communication strategies can pave the way for potentially significant rhetorical effects may partially result from our observation that they often appeared in combination. A designer might opt to use many less obvious framing strategies to convey a visualization story, so as to reduce the appearance of bias that can result from extreme usage of a single strategy.

This ranking excludes several techniques that affected nearly all visualization, albeit to different degrees. These are variable selection, default views, knowledge assumptions, and visual contrasts. These naturally occur very frequently (e.g., an infinite number of variables cannot be visualized; a starting view for the visualization must be chosen; some knowledge must be assumed to communicate at all, such as a rudimentary ability to read charts; the goal of visualization is to compare data using vision). An insight to be gleaned from even these, however, arises when one considers that possible alternatives do exist, but appear to be unconventional. Choosing a default view, for example, may be unavoidable, but the choice of a single default view for all users is not a given. Designers might dynamically choose default views in cases where the goal of the visualization is less specifically focused on a single intended interpretation. This particular implementation was not observed however.

Some techniques appeared together quite frequently. Data source citations tended to appear with other provenance techniques (i.e., methodology citations) more often than they appeared alone. While knowledge assumptions are on some level unavoidable, analogy, parallelism or other linguistic-based similarity techniques nearly always occurred with more extreme assumptions. An example is the title 'The Arab Powder Keg', which assumes that the user is familiar with the powder keg reference. Again, however, we note that this trend is not inevitable. A designer wishing to create a chart likely to be understood by the largest number of users could annotate the presentations with definitions in smaller type so as to include users without the requisite prior knowledge. Another notable pattern was

the tendency for rhetorical questions to be used with implicit goal suggestions. In these cases, a question was posed that was most easily interpreted as ironic or pedantic in light of other annotations that directly instructed users to look for particular patterns.

A pronounced pattern throughout our analysis was the observation that the effectiveness of individual strategies depends on references to other layers of the presentation. This occurs despite the way that some categories are more closely associated with certain editorial layers (i.e., linguistic rhetoric mapping to annotations), A clear example is described below for the 'Poll Dancing' visualization (Fig. 7, Section 4.2), where a double-entendre in the title depends on several visual metaphors in the graph. This highlights the nature of narrative visualizations as multimedia artifacts that can't easily be reduced to visualization alone.

3.3 Viewing Codes

The concept of **viewing codes** is an adaption of theories presented in semiotics (e.g., [2]) that capture how attributes of the receiver of an artifact influence interpretation. Viewing codes are the cultural, perceptual, cognitive, and psychological lenses that guide how an end-user (or community) interprets a representation. This concept sheds light on the constraints imposed on end-user interpretations by habits and beliefs that are not explicitly contained in the visualization but rather implied by visualization elements. Below, we discuss how a distinction between **denotation** and **connotation** becomes important with regard to discussions of viewing codes.

In semiotic studies, codes are thought of as systems of related conventions, accumulated over time, that correlate signifiers, or symbols or representations, with signifieds, or meanings [10]. In InfoVis, for example, the conventions that dictate what end-users expect to be communicated by given visualization formats are codes. Bar graphs, for example, are conventionally associated with discrete trends, while line graphs are associated with temporal trends. Prior experience with these graph types informs expectations when faced with a new graph. When non-temporal data are graphed in a line graph, users tend to frame their interpretations of the data using language associated with trends, such as "as a person gets taller they become more male" [54].

Cultural codes describe the social norms and wider beliefs of a culture that a designer can target to suggest a particular interpretation. **Individual-level codes** can be higher-cognitive constraints (e.g., abilities) or more emotionally-based patterns of reaction. Empirical literature demonstrates how individual differences deriving from spatial intelligence (e.g., [9]) as well as prior knowledge can affect visualization interpretation [15, 56] and even bias perception [19]. For example, individuals differ in their interests and prior knowledge regarding various types of news. Consequently, these differences lead to differences in how users interpret the implications of the story in a narrative visualization.

Perceptual codes constrain what is salient to the user given human visual perception tendencies, such as gestalt principles of continuation, common fate, and closure [47]. Perceptual tendencies can combine with internalized knowledge to form additional types of codes such as **textual codes,** the conventions associated with the presentation and interpretation of text. With regard to online information visualizations, these include the common positioning of the title either in the top center or top left of the presentation, the inclusion of source and designer credits toward the lower right or left hand corners of the layout, as well as the assumed left-to-right reading style in many Western cultures noted by [38]. Similarly, **aesthetic codes** combine perceptual as well as shared yet subjective preferences for a particular style of presentation. In the tradition of visualization design that prioritizes high data-ink ratios, minimalist techniques such as colorless backgrounds and an avoidance of non-necessary ornamentation create a particular aesthetic code that can affect a user's judgment of the quality of a visualization.

A given element of a visualization-based presentation (whether textual, visual, or a combination) can activate individual or cultural viewing codes in several ways. *Denotation* refers to descriptive elements, including either textual or visual statements (such as iconography) that directly attribute features to objects. In the above example of users' differing expectations of bar versus line graphs, the height of the bars directly conveys the value for each bar's group for the y-axis variable (e.g., cost, score, or another quantity of interest). Likewise, the location of the points comprising the line directly conveys the value of the y-axis in the line graph. Users familiar with how to read a bar and line graph use this straightforward mapping to interpret the data. *Connotation,* however, refers to cases where a secondary symbol cues, but does not directly associate, a meaning. This form of communication better describes why users of a bar graph are more likely to interpret the data as discrete rather than a temporal trend, while line graphs tend to evoke temporal interpretations regardless of the data [54]. Users have come to associate each graph type with particular data types (discrete categories and temporal trends), and the format itself activates the code of this expectation despite the lack of explicit reference.

4 Illustrating Visualization Rhetoric

Two case studies are used to demonstrate the kinds of insights that the visualization rhetoric framework provides into the interaction of specific design strategies, their communicative functions, and the extra-representational factors that constrain them. The first example, 'Mapping America: Every City, Every Block' highlights how the editorial layers described above can be used to convey meaning, and how specific techniques employed at these levels represent omissions and emphases of some data over others. The second example, 'Poll Dancing', demonstrates how viewing codes can be cued through design elements in practice, either through direct communication (denotation) or implicit suggestion (connotation).

4.1 'Mapping America' Visualization

The United States Census represents a nation-wide attempt to provide an objective view of the demographic distribution of the country. The New York Times Graphic Department's 'Mapping America: Every City, Every Block' [6] interactive visualization depicts 2010 U.S. Census results. Rhetorical techniques are employed at the four different editorial layers of the visualization (described in section 3.1) to convey the comprehensiveness of the data collection. At the level of the data, the choice to use actual census results rather than third-party summaries of the data conveys the truthfulness of the visualization as a non-biased depiction. The annotation layer communicates this choice. In this example, social annotations are provided in the form of comments in the right side bar that draw attention to important features and suggest conclusions based on the data. The annotation layer is also leveraged in this example for **data provenance** purposes, through a *methodology citation* behind the depiction as well as specific data *source citations*. The latter citations may betray *knowledge assumptions* on the designers, who wish to appeal to a user's prior knowledge of the scope of the census data collection. In the context of visual journalism, such techniques shape users' interactions and interpretations by *signalling transparency* such that various beliefs associated with objective information visualizations as a journalistic standard [23] are cued. Another annotation works as an **uncertainty representation** that conveys impartiality by referencing *the inferential limits* imposed by a margin of error. The *redundancy* in the title annotation phrasing, "Every City, Every Block" [6] emphasizes the comprehensiveness to the portrayal. Similarly, techniques using the interactivity layer include a *default zoomed-out view* of all of New York City (the largest US city and presumed home of the default New York Times user) and additional zooming features for gaining an even more holistic view of the country. A *search bar* allows users to explore data for any US region using addresses, zip codes, or city names of personal significance to them. Together, these choices convey a sense that the visualization provides a relatively unobstructed presentation of all information

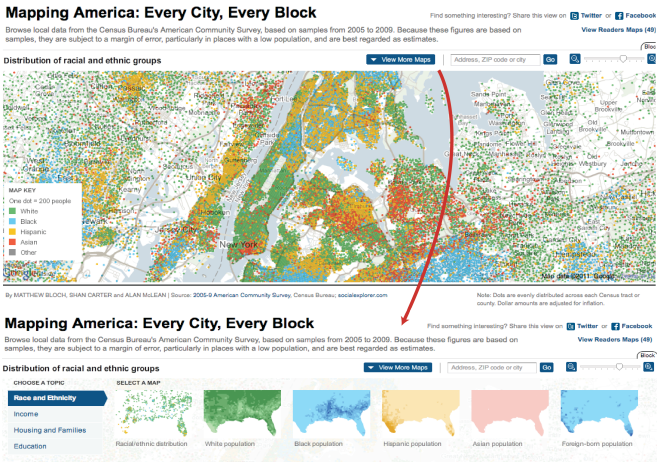


Fig. 6: 'Mapping America …' by Bloch et al. of the NYT graphics department [6]. Users can navigate from the initial view in the top frame to a menu of additional maps using a clickable button.

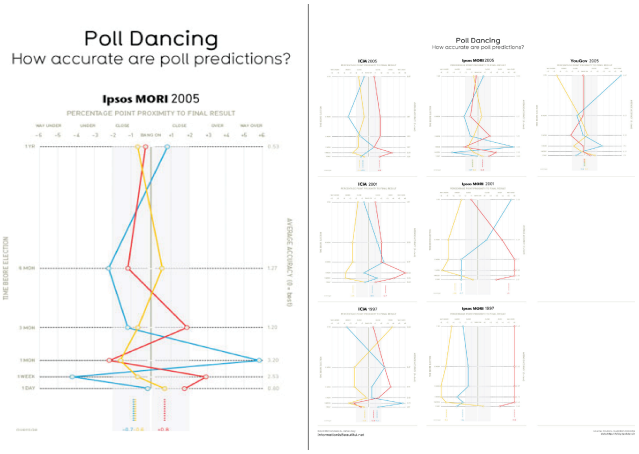


Fig. 7: Partial (left) and full (right) view of David McCandless' 'Poll Dancing: How accurate are poll predictions?' [29].

necessary to decode the patterns inhering in the data. The depicted story of the spatial distribution of ethnic groups is further supported by consistent mappings, such as of groups to colors that are applied identically to data points in the multiple views.

Yet like any visualization, less impartial choices are evident as well. The choice to represent the families part of the 'Housing and Families' category with a single variable on 'Same-Sex Couples' represents an example of information access rhetoric through **metonomy**, as it omits other families like two parent or single person households. If additional data was available from the source but the designers excluded it, this choice can be read as an implicit suggestion to end-users that they are expected to find this information more interesting than other family-based variables. The visual representation carries further emphases on particular views of data. The choice of which variables are *mapped to salient pre-attentive channels* [51] leads those variables to be more salient in the end-user's interpretation. Here, the use of color leverages the pre-attentive qualities of this visual encoding channel to represent racial and ethnic groups, subtly privileging this information.

As described above, interactivity can be used to promote exploration of specific subsets of the wider range of available information, subtly privileging some information over other information. For example, an emphasis is put on the race and ethnicity information by a default view that **anchors** users' interpretations so that they are most likely to be formed based on this dimension of the data. By clicking on a 'View More Maps' button in the example, users are taken to a *menu* of additional choices, which enforce the priority of the Race and Ethnicity view by listing this first, making it more likely that users will interact with these views as a result of common navigational conventions. Exploring these additional variables reveals some *ambiguity in variable definitions*; the requirements for membership in the Race and Ethnicity categories of 'Foreign-born population' and 'Asian population' are not explained, leaving uncertainty as to what extent these groups overlap. While ambiguity techniques can function oppositely to omission techniques by providing a user with the possibility of several differing interpretations, they also omit more specific information such that a user is prevented from knowing with certainty whether her interpretation is supported. Faced with ambiguity, a user is able to choose for herself which definition or reading of a visualization element to assume. She may default to the definition that better supports an interpretation cued by her individual viewing codes, or unique knowledge and beliefs. This can work in favor of an intended interpretation on the part of the designer, such as in cases where providing the full unambiguous information might eliminate the plausibility of a highly engaging yet flawed interpretation.

4.2 'Poll Dancing' Visualization

A second example shows more clearly how extra-representational constraints can also significantly influence an end-user's interpretation. David McCandless' 'Poll Dancing: How accurate are poll predictions?' [29] (Fig. 7) visualization summarizes the accuracy of political poll predictions from several years and polling agencies in a small multiples presentation of vertical line graphs. In each individual graph of one agency's predictions over a year, colored bars representing the political parties are drawn to connect data points positioned on the y-axis according to the amount of time prior to the election and on the x-axis according to whether the predictions fell over (to the right) or under (to the left) of a centered vertical line representing complete accuracy (or error of zero). Despite the apparent straightforwardness of the representation, analysis from a rhetorical standpoint provides insight into several layers of meaning implied as a result of design choices. Which of these alternate levels of meaning an individual user prioritizes depends on the **viewing codes** that constrain the interpretation, representing a second important insight that can be gained from rhetorical analysis. In the 'Poll Dancing' visualization, the framing of the poll predictions as 'dancing' in the title annotation lines brings to mind cultural associations with dancing as well as potential associations that stem from a user's unique beliefs and knowledge about dancing. On a more basic level, the word 'dancing' combines with the juxtaposition of the visually-jagged line graphs in a *visual-linguistic metaphor*. Another type of **visual metaphor** is evident in that the variation, or directionality and distance to the center 'accuracy' line of the colored lines in the individual graphs, results in a *visual noise* effect. This effect is connected to the dancing association cued by the title based on a similarity between the *parallelism* inherent in the perceptual approximation of movement achieved by the jagged lines and the movement in dancing. In this case, the brightly-colored lines also naturally pop out against the muted grey and white background as a result of a perceptual codes. An *aesthetic code* that equates minimalism with representational impartiality may have motivated the colorless background and low contrast annotations.

Returning to the central metaphor, based on her prior experience and associations with political poll predictions, a user might interpret the association drawn between political poll predictions and the act of dancing as a light-hearted presentational technique that does not necessarily comment on the value of political poll predictions. On the other hand, a user with a more skeptical prior orientation to poll predictions might interpret the dancing connection as implying a frivolous or amusing aspect that suggests the results should not be taken seriously. Hence, differences internalized in *individual codes* can significantly alter the message an end-user interprets.

Another possible level of meaning can also be inferred given the specific design elements and consideration of additional associations that might be created by the title and visual representation. The title 'Poll Dancing' implicitly *connotes* the identically-pronounced term 'pole dancing', referring to a form of entertainment and exercise that traditionally takes place in strip clubs. As such, a second form of metaphorical substitution, *double-entendre,* is used to cue a double-meaning to any users who are aware of the existence and term for 'pole dancing' in English. This meaning may gain further support through another **visual metaphor** cued by the choice to orient the line graphs vertically and to center the colored lines around the straight vertical line representing zero error. Users familiar with pole dancing may associate this vertical line with the pole that a pole dancer orients her movement around. This *connotation*, if cued in an end-user with a negative association with 'pole dancing' deriving from cultural stereotypes associated with the activity, might lead to an interpretation of the visualization's message as an even stronger value judgment on the worth of political poll prediction. This results from the way these negative associations with pole dancing are metaphorically transferred to political poll predictions.

Interestingly, *connotation* as that described above depends on *denotational* communication of meaning, as the denoted signs are used in connotation to imply a non-present meaning [2]. In the above example, the implication of pole dancing achieved by the vertical representation of the central "pole" relies on the same element that plays a directly descriptive role by representing the zero point (or accurate prediction).

5 Discussion and Future Work

The study of narrative visualizations offers an opportunity for increasing understanding of the complementary relationship between explorative and communicative dimensions in InfoVis. We suggest several important considerations for this space highlighted by our analysis, and note areas that may be fruitful for future exploration.

The effects of subtle rhetorical manipulation of information has generated sometimes surprising results in decision theory and political and communication studies. Applying a similar experimental approach to narrative visualizations is a natural parallel. Our work sets the stage for such studies by providing a taxonomy of specific information presentation manipulations used in narrative visualizations. Formal models that have been developed to capture the formation of user opinions as dependent on personal attitudes [35] similarly motivate future modelling of combined effects of rhetorical techniques and personal and cultural viewing codes on a user's interpretation in narrative visualization.

Acknowledging the distinction between denotation and connotation contributes to InfoVis design and theory by highlighting an epistemological tension that invades many narrative visualizations. This tension lies between techniques of "objective" charts informed by transparency ideals on the one hand, and the layers of connoted interpretation that can seep into or co-opt the basis of objectivity via rhetorical strategies on the other. The 'Poll Dancing' example leverages the visual representation to precisely depict trends in forecasting. At the same time, connoted meanings imply that poll predictions may be best characterized as "entertaining" rather than rigorous or scientific. The fact that both modes are possible within the same space may explain why such visualizations are engaging in ways that is difficult for numeric representations alone to achieve. The intriguing tension or interplay that results from combining seemingly oppositional techniques may help explain how rhetoric can exert a positive influence in visualizations. Future work includes devising means of assessing narrative visualizations such that these positive influences are recognized, while still acknowledging the potential for rhetorical decisions to negatively affect a user's accurate interpretation of data.

A frequent example of such a productive tension in our sample is the tension observable in some narrative visualizations that appear to be concerned with presenting their work as credible even in cases where the journalist may have taken some liberties in preparing the graphic. This is likely the influence of journalistic notions of transparency, where creators are expected to be upfront about their knowledge as well as what they don't know [23]. In many examples, the journalist's presence is explicitly stated, such as through notes about how a visualization contains 'predictions' or 'forecasts' at the bottom of the graph (see Fig. 4). These acknowledgements may play a double role in the sense that they strengthen the sense of the journalist's or designer's integrity despite explicitly pointing to a lack thereof. This observation dovetails with the observation that codes or conventions appear to operate in narrative visualizations. Not only do transparency clues suggest that an end-user should believe the specific interpretation being emphasized in the visualization, they also implicitly suggest to users a preferred way of making similar decisions when viewing other visualizations. Insight from critical media and semiotic studies suggests that such codes are dynamic systems that change over time [10]. Many professionally produced narrative visualizations form part of a larger system of meaning and rhetoric, knowledge of which guides an informed user on how to interpret the particular example. By giving more attention to the development, maintenance, and propagation of such conventions in information visualization, researchers and designers alike stand to gain control over dimensions of interpretation that have remained mostly unaccounted for or underexplored.

A related discussion prompted by this work concerns the degree of intentionality that can be assumed behind the rhetorical effects achieved in narrative visualization. In analysis we noted all possible, although not necessarily intended, framing effects of design choices. Future studies could involve interviewing visualization creators to assess their cognizance and intentionality of these methods. In any case, the power of rhetorical techniques to manipulate user interpretations supports a call for increased responsibility among designers to consider the possibly unintended effects their choices may have. This could, for instance, entail adopting a scenario-based design approach where different scenarios representing different viewing codes are considered in an attempt to project how design decisions could push an interpretation in different directions.

Finally, our analysis concentrated on professionally designed visualizations, yet it is possible that users contribute to a visualization story. Examining patterns in user reactions to visualization rhetoric is a natural next step given the prevalence of commenting features in online visualization systems (e.g., [49, 50]). A specific aim for future work concerns the possibility for integrating rhetorical and communicative features into exploratory visualization tools, including collaborative visualization systems [11, 42]. Developing a deeper understanding of rhetorical devices and styles for communicating meaning, particularly those that add information such as annotations of methodology and uncertainty representations, could allow analysts to better communicate their findings to remote or asynchronous others, improving communication of insights in collaborative visual analytics.

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