

# Analyzing Design Strategies for Narrative Visualization

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## ABSTRACT

In the past few years, telling stories with data (narrative visualization) has been receiving progressive attention, due to many benefits of its use. Seminal works in the field mapped the main characteristics involved in designing this kind of visualization. However, through analyzing a set of related academic studies and comparing them with such seminal works, we identified unexplored characteristics. The main contribution of this paper is an extension of the original narrative design space proposals, identifying what main design strategies adopted in academia and research opportunities are, regarding design and interaction of the narrative visualization spectrum.

## ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

## Author Keywords

Narrative Visualization; Information Visualization; Design Space

## INTRODUCTION

With the increasing amount of data generated by different sources, data visualization has become increasingly relevant to create visual representations that improve exploration, analysis and communication of such data. Thus, novel ways of data representation have been proposed in the academic field and also outside this domain. Beyond the power of visualization to communicate information, facts and opinions, data visualization researchers have begun to consider visualization as a medium to tell compelling data stories.

Storytelling (which refers to the expression “to tell a story”), in the visualization context, can be defined as an ordered sequence of steps, with a clear defined path. These steps can include many types of medias, such as texts, images, visualizations, video or any of their combinations [27]. This strategy of integrating visualization techniques with storytelling enables

to demonstrate temporal structures and causal relationships between facts and events, for instance.

Gerson and Page [20] published one of the first works that intersects the information visualization and the storytelling areas, in which they argued that visualization has to present information as clear and concisely as possible. For them, narrative visualization could help doing so, because it allows information to be revealed in an effectively way, “*as if an audience was watching a movie.*” Since then, many works in this area have emerged focusing on different aspects [39, 41, 46, 24, 25].

In our study, we focus on narrative visualization [39] as a way of telling story with data. Whereas some researchers [39, 41] performed previous analysis of narrative visualizations from the industry<sup>1</sup>, we propose an analysis of narrative visualizations created in academic works under the design space lens.

Our purpose is to understand this design space - the design strategies used in narrative visualizations - to enable the identification of ways to design clear and concise narrative visualizations. It is aligned with the grand challenges for HCI researchers [40] related to the topic “Accelerate analytic clarity”. Our main goal is to map the design space of narrative visualizations developed in the academic context. More specifically, our main contributions include:

- the analysis of which interface aspects the authors were concerned to report;
- the design space extension of the studied seminal works, by including the techniques used in academic works;
- the most explored design space components;
- discussion about some unexplored elements; and
- some initial research opportunities.

This paper is organized as follows: in the next section we present the background on Narrative Visualization. After that, we describe our methodology as well as the identified/proposed design space extension. Moreover, we summarize the use of design space (Design Space Analysis Summary) and, finally, we present our conclusions and point out some initial research opportunities.

<sup>1</sup>We consider as industry those narrative visualizations created outside the academia.

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## BACKGROUND

In this section, we intend to discuss some topics that are related to our work. Specifically, we bring some concepts related to the area of data visualization, as well as to the area of narrative visualization.

### Data Visualization

According to Ward [45], visualization can be defined as the communication of information using graphical representations, which provides an alternative or complement to textual or verbal information. The goal of visualization is to aid the understanding of data by leveraging the human visual system ability to recognize patterns, spot trends, and identify outliers [22]. If visual representations are well-designed, they can replace intuitive cognitive calculations with simple perceptual inferences and improve comprehension, memory, and decision making.

The terms data, information and knowledge are extensively used with visualization, even to denote data types, such as data visualization, information visualization, and knowledge visualization [10]. Information visualization configures a research field in computer science that started to be formally recognized in the 80's [21]. Since then, this field has grown significantly, being used today in several areas of human knowledge and applications [45].

We agree with Keim [26], when he argues that if there is no possibility to adequately explore large amount of collected data, this would turn into useless information. In this scenario, information visualization is necessary to provide resources for users to explore information adequately and gather knowledge from database, otherwise, according to the author, database would become data 'dumps'.

Card et al. [9] propose a reference model of information visualization. This model includes all steps necessary to create and use visualization systems, from data manipulation until its transformation into a graphical form. In addition, the model also includes users' manipulation in both data and visual stages. The representation of this model can be visualized in Figure 1.

### Narrative Visualization

The relationship between data visualization and storytelling is seldom articulated clearly, but many researchers have discussed this subject as well as ways to incorporate storytelling in visualizations [39, 41]. *Narrative visualization* is an expression that Segel and Heer [39] used to refer to visualizations that incorporate storytelling into their design. They developed a framework that suggests design strategies for narrative visualization in order to prevent some difficulties when the user is given freedom and control over the narrative.

According to Segel and Heer [39], narrative visualizations differ from traditional forms of storytelling in important ways. Formerly, data visualizations were used to support traditional forms of storytelling [14]. Nowadays, there has been a great effort to transform visualizations in an independent form of storytelling that can exist without the support of traditional forms of storytelling, such as video or text [17].

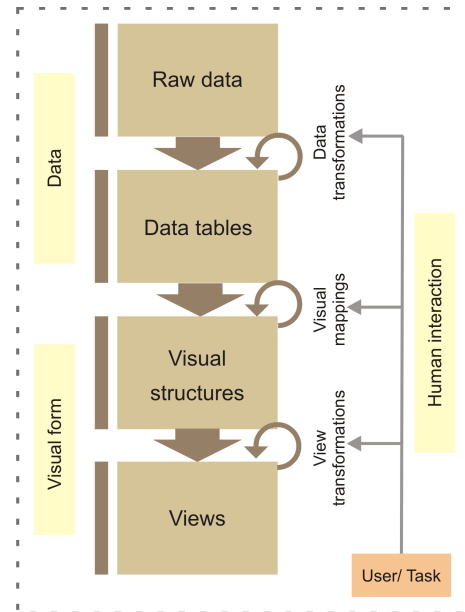


Figure 1: Reference model proposed by Card et al. [9].

To Figueiras [18], the combination of storytelling with data visualization has been pointed out as an efficient way to represent and make sense of data. Narrative elements in data visualization are able to provide explanation about the subject, and often support a structured interpretation form that usually does not exist in traditional data visualization. Diakopoulos [14] discussed an issue in the visualization area about how beneficial or not it is to introduce storytelling in data visualization. According to the author, if well done, storytelling can be a powerful way to create a structured interpretation path, because the way a story is presented to a user associated with the interactions afforded with the visualization will impact the possibilities of data exploration.

Heer et al. [23] investigated the design of history mechanisms for information visualization and introduced a design space analysis of history systems. They developed a prototype history interface for the Tableau software and their analysis served as a useful guide for navigating the design decisions they faced while architecting history interfaces to support visual analysis and communication. Tableau's graphical histories was one of the first visualization systems that incorporated storytelling into its design, allowing users to review, collate, and export key points of their visual analysis. A primary contribution from their work was a design study on history tools for visual analysis.

In order to improve the definition of what constitutes a visual data story, Lee et al. [41] did a detailed description of the activities, artifacts, and roles involved in the storytelling process in visualization (which is called here as data visualization with storytelling). They discussed a more encompassing look at the visual storytelling process to uncover open areas for research. The visual data storytelling process was proposed as a working model that can contain many loops and multiple occurrences of each component: exploring data, making a story, and telling

a story. In Figure 2 we can see these components and the roles that visualization storytellers assume. This process involves transforming data into visually shared stories via exploring data, making a story, and telling a story, and the progression of these three components does not need to be linear.

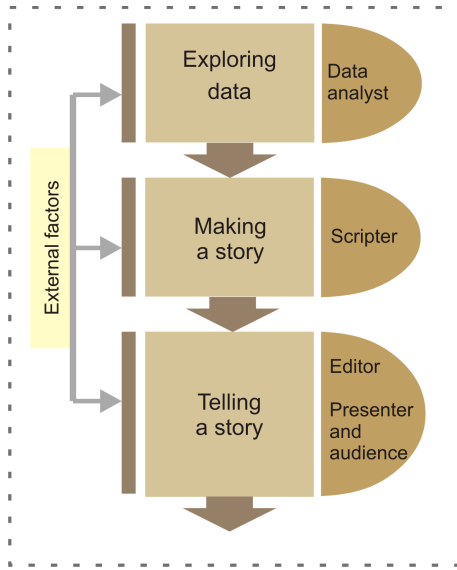


Figure 2: Storytelling process proposed by Lee et al. [41].

According to Figueiras [17], more research is needed to understand which storytelling techniques can be used and if it is possible to build a set of techniques that would work for different sets of data. Our work is an attempt to progress the research in this field, charting the landscape of the current narrative visualization design space and its possible extension.

### NARRATIVE VISUALIZATION DESIGN SPACE

Visualizations elaborated with the intention of telling stories to their audience need to incorporate elements that would give them a "story tone". In literature, we were able to find two works [41, 39] that analyzed several narrative visualizations, developed mainly from news web sites. Through this analysis, they identified some components that could be used to construct such visualizations, forming what Segel and Heer [39] called "narrative design space".

The narrative design space proposed by Segel and Heer [39] is composed by three categories: *genre*, *visual narratives* and *narrative structures*. Firstly, *genre* is how the story is organized. The authors identified seven different genres (*Magazine Style*, *Annotated Graph/Map*, *Partitioned Poster*, *Flow Chart*, *Comic Strip*, *Slide Show*, and *Film/Video/Animation*), which are represented in the Figure 3.

The second category refers to *visual narratives*, which can be understood as devices that assist and facilitate the narrative. This category has three sub-categories, which are Visual Structuring, Highlighting and Transition Guidance. The Visual Structuring are the mechanisms that help to structure the narrative in terms of how the progress of the story is presented in the interface, and some of the techniques that can be

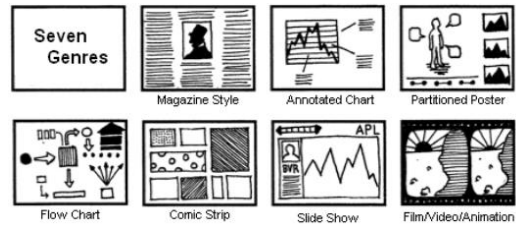


Figure 3: Representation of narrative genres identified by Segel and Heer [39].

cited as example are Progress Bar/ Time Bar and Checklist Progress Tracer. The second one, Highlights, intends to give some emphasize into specific parts of the story, through Zooming or Close-Ups, for instance. Lastly, Transition Guidance sub-category is regarding the ways of moving forward and backward into the story, which could be done, as an example, through Animated Transitions or Viewing Angle.

*Narrative structures* are the visual and non-visual structure mechanisms present in the interface. This category also has subcategories, which are ordering, interactivity, and messaging tactics. The ordering subcategory is related to the paths that users can take into the story (linear, random access or user directed path). The interactivity are the existing mechanisms to interact with the interface components, such as Hover Highlighting / Details or Filtering / Selection / Search. Finally, the messaging subcategory are the mechanisms to communicate or give explanations about parts of the story, and some of its techniques included Captions/Headline and Annotations.

The authors also identified that narrative visualizations were in the spectrum of author-driven and reader-driven approaches, which are, basically, how much users can explore data, how many paths they can run and how interactive the interface is. The author-driven approach provides a linear ordering of scenes, heavy messaging and no interactivity, whereas the reader-driven one neither has a prescribed ordering, nor messaging, and has free interactivity. All examples in their dataset were a mix of both approaches (author and reader driven). The authors also present three hybrid models (that combine both approaches in different levels from one another), that emerged from their analysis: *Martini Glass Structure*, *Interactive Slideshow*, and *Drill-Down Story*.

Later, Stolper et al. [41] also analyzed visualizations that were created outside the academia. Different from Segel and Heer's work, the authors restricted the analyzed corpus by including just narrative visualizations that provide a way for the author to specify the narrative ordering. The categories found by the authors were *Communicating Narrative and Explaining Data*, *Linking Separated Story Elements*, *Enhancing Structure and Navigation*, and *Providing Controlled Exploration*.

*Communicating Narrative and Explaining Data* is the technique used to explain or provide some clues for the readers, using, for example, annotations or audio narration. *Linking Separated Story Elements* provides manners to connect elements that are related in the story and which can be done, for example, through colors or interaction (highlighting some

connected elements when one of them is focused). *Enhancing Structure and Navigation* is the technique used to explore the story. Finally, *Providing Controlled Exploration* can be understood as interaction techniques that can change the story somehow.

Both models are not mutually exclusive, given the similarities found by Stolper et al. [41]. These similarities, in addition to our analysis (which contemplates the extension of this design space) are described in another section, besides our analysis findings.

## METHODOLOGY

Since this work aims to analyze narrative visualizations presented by the academic community, we search works available in some of the main digital libraries (ACM digital library, IEEE Xplore digital library, Elsevier ScienceDirect, Wiley and Google Scholar). We included papers that encompassed - in the abstract, title or keywords - the terms “story”, “narrative” or “storytelling” and the words “visualization” or “visual”. From this initial search, we selected 71 papers that contained these mentioned criteria. Finally, we analyzed these 71 works and selected 25 that presented an implementation of narrative visualizations.

Apart from the works by Segel and Heer [39], and Stolper et al. [41], that had the analyzed visualizations available online, in most cases the visualizations described in the analyzed papers are not available, and we could not explore them. Due to this fact, we restricted our analysis to what the authors mentioned. Despite the fact that this could limit our analysis, considering that authors could omit some important aspects of visualization, we tried to understand what aspects of visualization and what components of narratives are being reported in these works.

We started with the work of Segel and Heer [39] and, then, we analyzed the design space described by Stolper et al. [41], adding the components that were not previously found in Segel and Heer’s work. Finally, we analyzed our set of works, by coding the techniques used by the authors. When a new technique was found, we analyzed it and added it to the proper category/sub-category. At the end, we constructed the extension of the design space, filled with the list of techniques used by the authors, as shown in Appendix A.

## DESIGN SPACE EXTENSION

In this section we present the results of our analysis. We describe the extension of the design space, presenting the differences found by our analysis, as well as the current practices used by the authors, in the academic field, for each design space category.

### Genre

Regarding the narrative genre, we are able to find an additional technique. *Timeline* was used as a template for telling stories of events that occur over time. In this case, we considered *Timeline* as a genre, due to works that just presented a timeline for telling their stories. In addition to time representation, other narrative techniques were used, such as those related to entities, forms to check progress or messaging points of

the story. Figure 4 shows the complete list of genres. The new genre that was found in our analysis is highlighted in green and the others are those that already existed in Segel and Heer’s design space.

Genre	Magazine Style
	Annotated Graph/Map
	Flow Chart
	Comic Strip
	Slide Show
	Film / Vídeo / Animation
	<b>Timeline</b>

Figure 4: Complete list of design space genres. The green color indicates the new genre found through our analysis.

### Narrative Structure

The ordering sub-category (paths that readers can run) does not have any changes. To the interactivity sub-category (how users can interact with the interface), we found five new options: *Sort* (to change the order of presented information), *Add Data/Notes* (to add or remove data of datasets or add notes in specific points of the interface), *Manually Organization* (to organize how elements are displayed on the screen), *brushing and linking* (to present several visualization methods to overcome the shortcomings of single techniques), and *comparing data* (to replicate the current visualization and change the criteria, in order to compare different central points with the same template). Finally, in relation to the messaging sub-category, we identified only one new approach to provide details of the story, which is *audio*.

A list with subcategories of this category, as well as the techniques for each of them can be visualized in the Figure 5. The items in orange are the ones that were originated from Stolper et al. analysis, and the items in green are the ones that were originated from our analysis.

### Visual Narrative

Originally, in Segel and Heer’s work [39], visual narrative has three sub-categories: visual structuring, highlighting, and transition guidance. Stolper et al. [41] also identified *Linking Separated Elements*, which have the goal of making connections between different stories of elements present in the interface, understood by us as a new sub-category in the visual narrative category. In their work, three different forms of linking were identified, through *interaction*, *color* and *animation*. All of these techniques were used by works among the selected papers, except *animation*. In addition, we found relations expressed by *explicit visual relation* (through, for example, lines or arrows), by *three structure* and by *approximation* (how the elements are organized in the interface).

In the new visual structure (named *Level*), the story is being shown on demand, through the path that users have chosen to take, and they are communicated about the current level of the

Narrative Structure	Ordering	Random Access
		User Directed Path
		Linear
Interactivity	Hover Highlighting / Details	
	Filtering / Selection / Search	
	Very Limited Interactivity	
	Sort	
	Add Data / Notes	
	Manually Organization	
Messaging	Brushing and Linking	
	Compare Data	
	Captions/ Headline	
	Annotations	
	Accompanyng Article	
	Multi-messaging	
	Comment Repetition	
	Introductory Text	
Summary / Syntesis		
	Audio	

Figure 5: Complete list of design space narrative structure. The green color indicates the new genre found through our analysis, and, in orange, the ones that were found by Stolper et al.

story. In general, an overview of the story is shown to users and, then, they are free to take any path they want (non-linear story). We found five novel highlighting techniques (that refer to techniques to direct users’ attention to specific elements) among the selected papers, which are through *size* (increase the size of some representation through some criteria), *grouped information* (clusters of data that are grouped by some criteria), *Slowmotion* (which is used combined with the animation genre [12] to emphasize parts that occurred in some important event and forward minor important parts of story), *color* and *suggestion* (when the system provides some suggestion of data, as, for example, the ten most cited hashtags [37]). Related to the transition guidance category, we have added the techniques that were identified by Stolper et. al., from which two of them were also used among the selected papers: *next/prev button* and *scrolling*.

A list with subcategories of this category, as well as the techniques for each of them can be visualized in Figure 6. The items in orange are the ones that were originated from Stolper et al. analysis, and the items in green are the ones that were originated from our analysis.

## General Discussion

Through the analysis of academic techniques to share stories with data, we are able to find some different techniques in each category of design space. In addition, we are able to identify techniques and genres that are most and least explored by the community. Regarding genres, partitioned poster is the most used (sometimes referred to as “dashboard” or “panel”), followed by graphs/maps with annotations and timelines, and others with a minor number of use. *Comic strip* and *magazine style* are the ones that were not used, maybe due to a different context, specially in the case of *magazine style*, which was a genre derived from news web site.

Most part of Visual Structuring techniques were used, except for *Stablishing Shot/ Splash Screen*. In seven works [49, 32, 16, 2, 6, 37, 47], we are not able to identify the used approach, regarding the visual structuring sub-category. On the other hand, most part of transition guidance is still unexplored, except for *Scrolling* and *Next/Previous*. In the case of transition guidance, we were able to identify just five works that mentioned its incorporation. That is because the major genres used were the ones that did not have changes of scenes: *timeline*, *relational*, *partitioned poster* and *minimalist cartographic route*. Providing some techniques to relate information is reported in most papers (except for 7 [1, 13, 35, 6, 11, 37, 47]), and that was mainly through an explicit visual relation, even though techniques such as color and interaction were used in some papers as well.

Regarding ordering, just two papers did not provide a way to identify how it occurs [33, 38]. The most used ordering were *Random Access* and *User Directed Path*. *Linear* was used mainly by the ones that incorporate animation as a genre technique. In the case of interactivity, *Hover Highlighting / Details* and *Filtering* are the most common techniques, followed by others with minor number of use. Finally, *Messaging* through *Captions* and *Headlines* are the most common used techniques.

We could verify that some techniques are more explored by the academia. For instance, we may cite partitioned poster genre, progress bar/timer tracker, explicit visual relation, linking and captions/ headline messaging. Besides that, there are some of them that remain unexplored, like most part of transition guidance, some forms of messaging and some of the previously found highlighting techniques (due to the fact that most part of used highlighting techniques are new in the design space).

## CONCLUSION

Narrative visualization is a research area that has been growing and receiving attention by the academia. Gershon and Page [20] were the first researchers to notice that storytelling could contribute to information visualization. Their main contribution was to conceptualize the idea. In 2010, the topic appeared again with Segel and Heer [39], who stated that data stories are an emerging class of visualizations. They provided a typology for classifying visualizations and generalized advice for designing narrative visualizations. In 2013, storytelling was pointed out as promising to open new avenues of visualization research, ranging from presentation to exploration and analysis [27]. Therefore, research focusing

Visual Narrative	Visual Structuring	Stablishing Shot / Splash Screen
		Consistent Visual Platform
		Progress Bar / Time Bar
Highlighting		Level
		Close-Ups
		Feature Distinction
		Motion
		Audio
		Zooming
		Size
		Grouped Information
		Suggestion
		Slowmotion/Fade in
Transition Guidance		Color
		Familiar Objects
		Viewing Angle
		Viewer (camera) Motion
		Continuity Editing
		Object Continuity
		Animated Transitions
		Breadcrumbs
		Menu Selection
		Scrolling
Linking Elements		Next/Previous Button
		Interaction
		Color
		Animation
		Explicit Visual Relation
		Three Structure
		Element Disposition (Approximation)

Figure 6: Complete list of design space visual narrative. The green color indicates the new genre found through our analysis, and, in orange, the ones that were found by Stolper et al.

on storytelling in visualization can be considered as a recent research area, and we perceived that a story is a powerful abstraction that can be used by data analysts to better understand patterns and data.

In this work we analyzed this area through the design space lens. Previous works [39, 41] identified which techniques are being used in the design of narrative visualizations. In both works, the authors analyzed narrative visualization available, mainly, in news web sites. Differently, we analyzed works in the academic context, in order to identify the techniques used by academic researchers, and try to establish a parallel between the previous design space identified by these seminal works [39, 41] and the design space retrieved from the analyzed papers.

By analyzing 25 works that were retrieved from some of the main digital academic libraries, we identified the techniques used by the authors, extended the previous design space with these techniques and identified unexplored elements of this design space, as well as some research opportunities.

As research opportunities, we envisioned that it is necessary to understand storytellers' needs and how they want to build narrative visualizations. Besides that, it is important to de-

open the studies concerning better ways to design narrative visualizations.

Furthermore, Segel and Heer [39] mentioned in their work that genres work better for different story types, and they depend on the complexity of the data and the story, the intended audience, and the intended medium. They also mentioned that there are trivial genres that fit better than others in some cases, such as the use of Slide Shows instead of Comic Strips, in the case of business presentation. However, in most complex cases, this remains an open research opportunity. Due to this fact, we believe that proposing new genres or models, associated with the context in which they could be applied (similarly to what was done by Elias et. al. [16] and Wood [47]), should also receive attention from the research community.

Given the dimension of the design space, we understand that it is necessary to deepen the understanding of each design space category, through studies that focus on each one of them (similar to the work of Amini et.al [4], that focused on narrative visualization through videos, or the work of Hulman et al. [25], that explored ways to structure linear narratives, focusing on the Transition Guidance category). Besides that, we also point out that comparing studies between the items of each category, e.g., comparing forms to highlight information

or different forms to make transition between the scenes, is also an interesting and important topic of study.

For future works, we will further the study of visualization techniques associated to storytelling elements and conduct studies on data analysts' needs regarding visualization. This study is part of other studies in progress that involve end-user development, narrative visualization, and data analysis.

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APPENDIX

NARRATIVE VISUALIZATION DESIGN SPACE OF ACADEMIC WORKS

[34]	[26]	[5]	[8]	[6]	[2]	[12]	[25]	[35]	[21]	[11]	[22]	[18]	[3]	[32]	[9]	[24]	[10]	[27]	[13]	[30]	[36]	[1]	[23]	[31]		
																									Magazine Style	Genre
																									Annotated Graph / Map	
																									Partitioned Poster	
																									Flow Chart	
																									Comic Strip	
																									Slide Show	
																									Film / Video / Animation	
																									<b>Timeline</b>	
																									<b>Minimalist Cartographic Route</b>	
																									Stabshing Shot / Splash Screen	
																									Consistent Visual Platform	
																									Progress Bar / Time Bar	
																									Checklist Progress Tracer	
																									<b>Level</b>	Highlighting
																									Close-Ups	
																									Feature Distinction	
																									Motion	
																									Audio	
																									Zooming	
																									Size	
																									<b>Grouped Information</b>	
																									<b>Suggestion</b>	
																									<b>Slowmotion/Fade In</b>	
																									<b>Color</b>	Visual Narrative
																									Familiar Objects (but still cuts)	
																									Viewing Angle	
																									Viewer (camera) Motion	
																									Continuity Editing	
																									Object Continuity	
																									Animated Trasictions	
																									<b>Breadcrumbs</b>	
																									<b>Menu Selection</b>	
																									<b>Scrolling</b>	
																									<b>Next/Preiou Button</b>	Linking Elements
																									<b>Interaction</b>	
																									<b>Color</b>	
																									<b>Animation</b>	
																									<b>Explicit Visual Relation</b>	
																									<b>Three Strucutre</b>	
																									<b>Element Disposition (Approximation)</b>	
																									Random Access	Ordering
																									User Directed Path	
																									Linear	Narrative Structures
																									Hover Highlighting / Details	
																									Filtering / Selection / Search	
																									Very Limited Interactivity	
																									Explicit Instruction	
																									Stimulationg Default View	
																									<b>Sort</b>	
																									<b>Add Data / Notes</b>	
																									<b>Manually Organization</b>	
																									<b>Brushing and Linkin</b>	
																									<b>Compare Data</b>	Messaging
																									Captions / Headline	
																									Annotations	
																									Accompanying Article	
																									Multi-Messaging	
																									Comment Repitition	
																									Introductory Text	
																									Summary / Syntesis	
																									<b>Audio</b>	