FROM DATA VISUALIZATION TO DATA STORYTELLING: CONTEXTUALIZING DATA THROUGH DIGITAL FILMMAKING

by

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The popularity of online video combined with widely available (and constantly improving) tools for visualizing data have recently opened up new opportunities for data visualization videos in the modern media landscape. This comes at a time when conveying scientific data to the general public is critically necessary. But while these data-driven videos are beginning to appear, there is very little available literature discussing strategies for evaluating and improving them.

Given such a lack of established literature, this paper will examine design principles and strategies that do exist in writings from influential information designers and visualization specialists. These principles and strategies were nearly all developed for static forms of media, so this paper will first explore ways to adapt those existing strategies to the time-based medium of video. It will then explore other video-specific advantages that can be utilized to further improve data visualization.
INTRODUCTION

The Age of Data and the Age of Video

The data driven “information age” of the 21st century is defined by information, and the need for the public to be able to quickly and efficiently make sense of that information has never been higher. Understanding the most important scientific issues of our time requires the distillation and interpretation of many datasets, and the biggest scientific issues of our time are some of the biggest issues the world faces, such as climate change and other looming environmental problems, disease, health & medical research, and world population dynamics. Science and statistics both describe these problems in detail and prescribe solutions. The data is often available for public consumption, but buried in studies and papers that are difficult for the public to digest. Without a basic understanding of the underlying data, systems and concepts, effective public discourse and effective science policy debates are nearly impossible. This makes informed science policy implementation equally difficult. It is not surprising then, that ideology sometimes trumps reason when that reason depends on information that, even if accurate and available, is difficult for the public to understand.

The need for public understanding of an increasingly data driven world comes at a time when the tools available for visualizing data are many and improving rapidly. The price-performance ratio of data analysis software, visualization software, and the computers that run such software have been increasing for decades, making them relatively affordable and available. The venues and media types available to data
visualization designers are varied and growing at a similar pace. But video stands out as a medium that is both prolific and under-analyzed with respect to data visualization.

Video is, in all its forms and by many measures, the most consumed type of media. The shift from traditional television to online video does not seem to have reduced the demand for video content at all, and has likely increased it (Nielsen). The on-demand nature of web videos has also made video increasingly accessible, and the ease of sharing videos via social media has led to, among other things, the unprecedented viral video phenomenon. These factors all indicate that, as a vehicle for disseminating information and educating the public, video is as valuable as ever - it is accessible, prolific, and has certain inherent advantages that make it effective as medium for data visualization and contextualization. While not necessarily the most appropriate medium for every type of data visualization, video has a capacity for communication in the 21st century that can't be ignored.

Very little has been written about visualization design strategies specifically for video. This paper will examine the themes and strategies that do exist in the broader field of data visualization, which were developed almost exclusively with print and other static display formats in mind. After an analysis of the relevant media-specific differences between those static display formats and video, I propose methods for adapting those themes and strategies to video. I then look beyond adapting existing strategies and explore ways to leverage media-specific characteristics to further advance data visualization through video. I use the terms “video” and “digital filmmaking” throughout
this paper, but the concepts discussed and the strategies proposed are relevant to the gamut of motion picture media including television, online video, and theatrical films.

Many of the visualization strategies used as a foundation for this discussion come from Edward Tufte, one of the most influential figures in the field of information visualization. Colin Ware, another respected figure in the field of information visualization, will provide additional strategies visualization to adopt and expand upon. Based on visual cognition research, Ware's analysis is typically more technical in nature than that of Tufte's, but both Tufte and Ware ultimately arrive at many of the same conclusions and advocate for many of the same strategies. Some of these strategies are directly applicable to video and won't require much attention, but some will require thoughtful adaptation in order to be useful in a different medium than they were created for, and those are the strategies that I examine depth.

**Media Specificity**

Before I discuss the adaptation of these themes and strategies from print to video, it is important to understand the relevant differences between the two mediums. The theory of media specificity argues among other things that “each art form has uniquely particular norms and capabilities of expression” (Stam 12). In other words, a particular medium is a tool well-suited for some things, and not so well-suited for others. Media specificity is demonstrated in a scene from the film *Close Encounters of the Third Kind* (1977). Aliens have managed to download an image of Devil’s Tower (their planned landing site) into the brains of some the films characters. One character paints a portrait
of Devil’s Tower, and another makes a sculpture. The 3-D nature of the sculpture is ultimately able to aid them in ways the painting cannot, and differences in the two media become clear.

Media specificity theory has been in existence since Aristotle, and the applications and extensions of media specificity theory have been debated and contested (Carol), but in general, contested parts of the theory are not applicable to the current discussion. It is valuable to use medium specificity theory not as a tool for judging the artistic merit of a project (where it gets controversial) but simply as a framework to think about what video can, and maybe should, do for data visualization – especially with respect to print, since print is the medium about which most design strategies have been written.

Print and video have several media-specific differences that are relevant to data visualization. The most obvious differences are sound, time, and to a lesser extent, spatial resolution. The time-based nature of video is something that comes up often in this analysis. Time is the element that puts video at an initial disadvantage in terms of visualization design. But it is also the element that allows video to open up new possibilities for visualization, in many ways overcoming those disadvantages in the process. It is the physical element that forces designers to treat video visualizations differently than static visualizations.

While the spatial resolution of print and other static forms of visualization are often higher than video, a more important factor is that dimension and resolution are often part of the design of static graphics. If a graphic is complex and needs to be large
in order to accommodate that complexity, it can usually be made large. Resolution is
dependent on design, instead of the other way around. Designers of video visualizations
typically do not have control over standardized video resolutions and aspect ratios.
Further, videos are often converted for display at multiple resolutions and at multiple
aspect ratios that are out of the control of the designer.

This challenge is not especially noteworthy since video and computer display
resolutions are high and constantly improving, but the issue represents something critical:
while the fundamental technical capabilities of print are clearly different from video,
there is much more to the discussion of relevant differences between the two mediums as
they relate to data visualization. There are major differences in how these media are
created, distributed, consumed and received, and these differences are as critical to the
design of visualizations as differences in their respective physical characteristics
(although these differences are certainly influenced by their respective physical
properties). It is a mistake to fixate on the physical specifications and capabilities of the
media; rather, the capabilities based on media-specific norms and expectations should
guide the pursuit of graphical excellence in video visualizations.

To shed some light on those norms and expectations, it is helpful to think about
the act of viewing these two mediums. We view static graphics on displays ranging from
newspapers, magazines, computers, tablets, and phones. Viewers sit at their desks, stand
in line at cafes, or any one of these countless “venues.” They view a graphic and try to
make sense of it. With good design and luck, viewers will understand the graphic and
gain new insight into the information it presents. The act of viewing a static graphic, in
print, on the internet, or elsewhere, is an act of *studying*, and while even if the graphic is not interactive *per se*, viewers actively decide when to stop studying it, and perhaps when to come back to it for a second look. The viewer expects the graphic will stay put indefinitely for their consumption on their terms. The viewer of the static visualization controls time, the designer of the visualization does not, and since viewers can customize the amount of time they devote to any given static visualization, such graphics can accommodate great complexity and density.

The number of venues in which to watch video have exploded in the last decade, and many of those venues (computers, tablets etc.) are the same venues in which we now view both static and interactive visualizations. But the act of viewing a video is still distinct from other presentations. Modern video, in all its forms and on all configurations of display, is still closely associated with, and a direct descendant of cinema and television, two mediums in which *information is fundamentally transient*. Due to its time-based nature, viewers expect videos to move and time to pass. Video is a medium we *watch*, not study and explore.

Most video content also takes a completely different distribution pathway to our eyes than does printed content. Most television and online videos are converted to one or more different formats (often smaller in resolution). They are usually compressed by algorithms that discard 95% or more of the original video data in order to conserve bandwidth and storage. This compression deteriorates effective resolution further, reduces color accuracy, and often introduces visual artifacts, digital banding and noise.
The result is that in many venues, and on many types of displays, video has a limited capability to show fine detail or subtle color shifts.

From these norms and expectations we can make at least one generalization about video and its information density capability with respect to print. It is a generalization I cite regularly in this essay: video has much lower available per-frame information density – sometimes due to lower spatial resolution or other technical considerations, but mostly due to the transient nature of the medium; the expectation of movement and passing time. But again, video can utilize its time and sound dimensions to increase density by other means, and this allows designers to explore new ways of presenting data.
Density, Clarity, and Graphical Excellence

Tufte advocates for efficiency in visualization. “Graphical excellence is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space” (Tufte, “Visual Display” 51). Ware echoes this: “...the goal of visualization research is to transform data into a perceptually efficient visual format...” (Ware, “Information” 25).

Tufte suggests achieving graphical efficiency through several information design strategies he groups into two overarching themes: information density and information clarity. Density and clarity are two concepts often at odds with each other but concepts that are also intertwined. Higher densities of information require more clarity, and more clarity allows for higher densities. Tufte suggests that more clarity in fact may demand greater density – clarity without density can leave a visualization “data-thin” and suspect.

Methods for increasing information density and clarity depend on many specifics of the data being visualized, and the goals of the particular visualizations. The art of good data visualization becomes apparent in these specifics – data visualization is never as simple as following a prescribed formula. Designs will depend on not only the dataset at hand or what the designer is trying to show in that dataset, but upon the intended audience, the types of visualizations they may already be familiar with, and many subjective aesthetic factors. Data visualization is a moving target: as visualization
techniques and styles change over time, so do viewers expectations and their ability to comprehend any given visualization efficiently (Ware, “Information”).

Nonetheless, a few consistent sub-themes for improving density and clarity do emerge from Tufte and Ware's writings. I have identified six such sub-themes and will use them to structure the remainder of this chapter. Those sub-themes are data ethics and data clarity, visual integrity, visual clarity, multi-dimensional data, repetition of visualizations, and micro-macro visualizations.

Data Clarity and Data Ethics

Data clarity and visual clarity are both critical to the success of a data visualization graphic. They are related concepts, but I will separate them for our own clarity of discussion. Data clarity is about identifying and prioritizing the right dataset, often before any visual design begins. Data clarity comes down to asking the right questions about the data.
In the graphic above, carbon emissions per unit area overlay a map of the U.S. It is a well-intentioned graphic showing higher emissions in and around cities, but not revealing anything new, since if we know anything about CO2 emissions we would already expect more emissions from areas with more people. To someone who knows nothing about the geographic distribution of population in the United States, the patterns this map shows might seem meaningful, but those patterns could actually be misleading without additional data, and in the context of the broader issue of carbon emissions and climate change, the graphic is not very useful. It answers the question: where is the most carbon being emitted. But with respect to climate change, it doesn't matter where carbon is emitted; it's total emissions that matter. The same visualization design using a dataset that accounts for one additional variable (number of people) provides better insight.
Essentially nothing has changed about the visual design, but this graphic paints a picture that is nearly the reverse of the previous map by showing areas of the country where the most carbon is emitted per person. This appropriately ties two dependent variables together – emissions per unit area, and population per unit area (total emissions are highly proportional to population). It answers a different question: what areas of the country are using carbon least efficiently. Both are accurate, but in the context of climate change, one answers a more useful question, and shows where carbon emissions are disproportionately high relative to population. The other mirrors a population density map at best, and at worst may lull viewers into thinking that those outside of densely populated areas are not a part of the problem. All good data visualization projects begin
with data ethics, regardless of medium. “Graphical excellence begins with telling the truth about data” (Tufte, “Visual Display” 53).

**Visual Integrity**

Telling the truth about data also requires a visual ethic. There are countless examples of graphics that “lie” with honorable datasets by poorly translating numbers to graphics. Here is a subtle but common example of a badly translated graphic:

Fig 3. A bar chart of motor vehicle registrations that implies a trend over time. The figure for 1955 breaks the continuity of the timeline, distorting the trend.

Whether mistranslated on purpose or not, the result is the same: viewers either come away confused, or worse (and more likely), they come away with the wrong impression about the data. Like data integrity, visual integrity is something data visualization designers in any medium must abide by. Tufte spells out two broad principles of graphical integrity. First, the graphic representation of numbers should physically be proportional to the numbers represented. Second, graphical elements
should have clear and detailed labels to “defeat graphical distortion and ambiguity” (Tufte, “Visual Display” 56).

   The first principle is relevant to any visual medium, and needs no adaptation for video. But the second principle needs to be re-interpreted slightly since detailed explanation through additional labeling doesn't always work well in video. It may suffice to say “minimize distortions and ambiguity by any means necessary,” since it could be accomplished by a number of methods in video, several of which are discussed below, such as visual attention cues or narration.

   Density Through Visual Clarity

   Achieving visual clarity is another challenge. Problems can arise due to specific human visual perception phenomena on the one hand, and subjective aesthetic preferences on the other. Adhering carefully to good strategies for data clarity and data ethics can produce visualizations that while both honest and successful in prioritizing the right data, are difficult to read and an overall visualization failure. Beyond clarity for clarity's sake, improved visual clarity also allows designers to incorporate more information into visualizations, thereby increasing density.

   Tufte devotes an entire chapter in *Envisioning Information* to separating and layering information as one critical strategy for visual clarification. He argues that “among the most powerful devices for reducing noise and enriching the content of displays is the technique of layering and separation, visually stratifying various aspects of the data.” (Tufte, “Envisioning” 53)
The following example demonstrates the essence of visual prioritization through layering. The Goode Projection map on the left gives nearly equal weight to all elements that are not all equally important. The dominant visual characteristics are latitude and longitude lines. Intersecting latitude, longitude, and continent lines create dozens of additional arbitrary shapes the brain has to work to not see. The map graphic on the right contains the same information, but uses different weights, and shades graphical elements based on their assumed relevance. Relevant information (presumably the world’s continents in this case) emerges as independent, easily recognizable shapes.

![Two graphical treatments of the same information](image)

Fig 4. Two graphical treatments of the same information

These principles (separating and layering) are described by a set of pattern perception phenomena known as Gestalt grouping laws – named for the German Gestalt school of psychology. Gestalt psychology describes many grouping laws, but at work here are the laws of proximity and similarity. They state that objects are perceptually grouped together if they are spatially near each other, or have similar shapes and patterns. The brain has a knack for extracting patterns out of chaos, and separating and layering are two strategies to help it find the right patterns in less time and with less energy. (Ware, “Information” 181)
These principles address the problem of visual clutter. They are critical to video since video's low-per frame available density only exacerbates the clutter problem. Video's always-ticking clock leaves little time for the parsing of a chaotic graphic. However, time can be used to visually stratify information and increase visual clarity, in turn allowing for more density. In video visualizations not all information needs to be visible at the same time. Solutions involve displaying data elements at staggered times – animating the first series of a plotted line graph followed later by a second, for example. Panning across several rows of numerals in order to keep them distinct is another example of temporally stratifying information. In the map example in Figure 4, clutter-inducing latitude and longitude lines could be shown only for a short time. Narration, color highlighting, or any number of other cues could help separate and group elements further.

Visual clarification is also embodied in Tufte's “data-ink ratio,” and two “erasing principles”: 1) “Erase non-data ink, within reason,” and 2) “Erase redundant ink, within reason.” (Tufte, “Visual Display” 96)

This strategy should be employed in video visualizations, but like all of these strategies it should be employed case by case, so Tufte's “within reason” caveat is particularly important. As demonstrated above, the low available per-frame density of video can exacerbate the clutter problems associated with extraneous ink, such as the thick latitude and longitude lines in Figure 4, so minimizing ink is beneficial. However, video's low per-frame density means that it does not accommodate subtlety well relative to static visualizations. Maximizing the data-ink ratio of a video visualization will
require different considerations and compromises than maximizing the data-ink ratio of a static visualization.

**Multi-Dimensional Data**

Increasing the number of represented dimensions in a visualization can increase the density, efficiency and, if well-executed, the richness of visualizations. “Graphical excellence is nearly always multivariate” (Tufte, “Visual Display” 51).

“Flatland” is Tufte's term for the two-dimensional medium that information designers physically work with, and, he argues, it is also the virtual prison from which the same designers need to escape. “Escaping this flatland is the essential task of envisioning information—for all the interesting worlds (physical, biological, imaginary, human) that we seek to understand are inevitably and happily multivariate in nature. Not flatlands.” (Tufte, “Envisioning” 12)

The idea of escaping flatland by incorporating additional data dimensions is illustrated in Joseph Minard’s famed graphic below (Figure 5) which shows the fate of Napoleon's army. It folds two additional dimensions of data (time and soldier count) into a two dimensional map. Adding temperature and direction brings the total dimensions of information to six.
Increasing density by incorporating many information dimensions is a matter of sensible mapping between information dimensions and physical dimensions. The lower per-frame density and additional available dimensions of video means that the mapping of these dimensions to physical dimensions will likely be different than the mappings for 2-D print media.

Six informational dimensions mapped to two physical dimensions works well in the high resolution print on which Minard’s graphic (Figure 5) originally appeared. In video, the same mapping will likely overwhelm viewers. The graphic in its existing form requires processing time that video cannot afford, and the necessary text labels are too small to read, yet too numerous to enlarge.
There are many interesting ways to map six data dimensions to the four available physical dimensions in video (two spatial dimensions, time, and audio). An obvious approach maps time (the x axis in the static version) to video's time dimension to create a flowing, shrinking path. This inadvertently obviates the need for a direction dimension, and bypasses a tricky design issue with the static graphic. In Minard's static version, combining time and horizontal space on the same axis means a distinction must be made between eastward travel and westward travel. Minard uses different textures to differentiate. Showing the path move over time in video time eliminates the need for such a distinction.

Other data dimensions, such as temperature, could be kept on the 2-D plane. They could utilize the time dimension through a counter or graphical gauge. Alternatively, those dimensions could be moved to the soundtrack and conveyed through narration.

**Repetition of Visualizations**

By repeating the same graphic with different data visualized in each iteration, a time dimension can be effectively incorporated into static visualizations. This is an example of Tufte's *small multiple* concept, which allow viewers to efficiently see changes and patterns against an unchanging graphic backdrop. (Tufte, “Visual Display” 42, “Envisioning” 67)
A simple escape from flatland is projecting a 3-D image on a 2-D medium, but multiple 3-D projections in Figure 6 add a fourth dimension (time), and even a fifth (type of pollutant), thereby increasing density and escaping further from the 2-D surface. The new dimensions allows for new patterns to emerge in the data. But Figure 6 also illustrates an unavoidable reality of increasing density: trade-offs. Information displays have limited resolution and screen space, so in this case the added dimension of time comes at the expense of detail in the individual projections. Increasing density in one dimension almost always requires designers to sacrifice density in another.

Many repetitions of small multiple graphics resemble the frames of a filmstrip, and in this sense small multiples translate fairly directly to video. Using time instead of screen space frees up per-frame density. Manipulating time provides additional advantages as well. A video with hundreds or thousands of repetitions allows new patterns to emerge that would not emerge in a static small multiple with only a few repetitions. The sheer number of repetitions available in video allows for the visualization of datasets that span long periods of time.
The time-lapse exemplifies this ability. By mapping sped-up actual time to video time, time-lapse videos show new patterns of information through compressed time. Below are several frames from a time-lapse video that compresses 24-hours of global air traffic into seventy seconds.

Fig. 7. Frames taken from a time-lapse video showing global air traffic.
Figure 7 renders the time lapse into three small multiples and suggests patterns of movement. The small multiples suggest a migration of air traffic from Europe to North America. This does reflect the actual flow of some air traffic, but it also misleads to a degree. The actual movement, apparent in the time-lapse, shows complex crisscrossing patterns of flow over the course of the day, and a massive amount of intra-continental traffic – neither of which are suggested in the static figure.

There is, as always, a penalty for the high temporal density found in time-lapses. By compressing time, less time is available for any given frame, and viewers lose the ability to inspect any single moment in detail.

**Micro-Macro Visualizations**

High-resolution displays and printed graphics excel at showing small scale details and large scale patterns in the same visualization. Visualizations taking advantage of this can increase density and clarity by allowing for readings on microscopic and macroscopic levels. In micro-macro visualizations, macro level patterns reveal new meanings, but specific data points are retained and kept accessible in micro level detail.

Visualization videos attempting to show the small and the large encounter immediate problems from video's lack of available per-frame information density. Showing large scale patterns may render small scale details so small they either blur into imperceptibility from lack of available spatial resolution, or they become so cognitively demanding they require undue viewer time to process. Recall that if viewers are watching a video they are anticipating time to pass and edits to occur. Imagine the stress
of running out of time to comprehend a finely detailed graphic that could disappear at any moment.

Video is a medium not well-suited for showing macro scale patterns and micro scale detail in the same frame (even on high resolution displays), but it can accomplish similar results by manipulating simulated 3-D space using motion and time. By guiding attention with movement (zooming, panning etc.) video allows designers to effectively increase the spatial resolution of its component graphics. By displaying the large and the small at different times, video is capable of displaying complex micro-macro visualizations.

Exploiting this idea further, video visualizations can simulate 3-D space to depict scales that would be impossible to visualize in static displays. Beginning with the Earth's moon, the video excerpted in Figure 8 shows the relative sizes of several planets and stars in the Milky Way. The video moves out and to the right in simulated 3-D space to reveal the stellar objects - each successive object being larger than the last. In each frame of the figure below the object at the center of the frame is the smallest object on the far left of the next frame. The largest object in the video is some 800,000 times larger in diameter than the smallest (2.8 billion km vs. 3,474 km). A static representation would be virtually useless, rendering all smaller objects as dimensionless dots.
Fig. 8. This video sequence begins with the moon and ends with the largest known star in the Milky Way. The last frame in this figure shows our Sun as a tiny dot at the far left. Source: http://www.youtube.com/watch?v=HEheh1BH34Q

The classic astronomy activity on the scale and size of the solar system is a similar example of a micro-macro visualization that is hopelessly unadaptable to static
visualization on paper. The activity involves creating a kilometer long outdoor
representation of the sun and all nine planets. Even at one kilometer, the earth is the size
of a peppercorn, making the visualization unsuitable for any display much smaller than
one kilometer. But such a representation is easily translated to video by simply
“traveling” the one kilometer (in either by simulating 3-D space or documenting the
activity in real 3-D space) and observing each object along the way.

This idea (scale) is explored and literally taken to its limits in *Powers of Ten*
(1977). The film (excerpted in Figure 9) may best demonstrate videos ability to handle
microscopic and macroscopic scales, and it is difficult to imagine its analog in any other
medium. It begins looking down at a square meter of a picnic at a park in Chicago, then
proceeds to zoom out twenty five orders of magnitude to show the known universe. A
narrator describes what viewers are witnessing at each step as a thin box outlines each
new distance measurement. The film then zooms in some forty orders of magnitude to
show a subatomic landscape at the limit of mankind’s small-scale knowledge.
Fig. 9. Frames from the film *Powers of Ten*. The film depicts scales from $10^{-17}$ meters to $10^{25}$ meters.
Adopting strategies to increase the density, clarity and overall efficiency of data visualization videos is critical. For many datasets and visualization projects, however, it is necessary to rethink the role of the visualization designer on a fundamental level. The greater the complexity of the dataset, the greater the necessity for guidance, and the more the designer must shift focus from the visualizations themselves to the guiding process.

As a cognitive concept, guiding (known in psychology as *attention cueing*) addresses the problem of high “visual search.” Visual search is described in psychology as the cognitive act of looking in a complex visual environment. Attention cueing has consistently shown positive outcomes when used in conjunction with complex visualizations. De Koning, et al, define attention cueing with respect to animation as “the addition of non-content information that captures attention to those aspects that are important in animation (e.g. coloring, arrows)” and found these techniques overcame the cognitive overload associated with complex animations requiring high levels of visual search.

In the same way that 2-D layering and separating can visually stratify information, reduce clutter, and focus attention on relevant data, guiding stratifies visual elements over time to achieve the same ends. Video accomplishes this by using any of the cueing devices it has at its disposal, including spoken narration, other sound cues, highlighting, movement, and simulated selective focus.
The short film *Wealth Inequality in America* (2012) excerpted Figure 10 achieves a high level of information density by using many of these techniques. It conveys multiple datasets though multiple visualizations, but by way of scripted narration that guides the viewer from one visualization to the next. The excerpted frames below show many of the 2-D visualizations strategies discussed up to this point, but there are important relationships between the represented datasets that are not conveyed without the accompanying narration from the film's soundtrack.

Fig. 10. Frames from *Wealth Inequality in America* (2012). Source: http://www.youtube.com/watch?v=QPKKQnijnsM

*Wealth Inequality in America uses* other temporal stratification devices in addition to narration in order to enhance clarity: an animated finger cues attention to important
information, and movement emphasizes important parts of the graphic. The narration sometimes adds data content, clarification, and context in addition to guidance.

Narrative is an important example of temporal stratification, and a form of guiding used in *Wealth Inequality in America*. Storytellers across cultures have used narrative for centuries to persuade, educate, inform and entertain, and story-based learning studies have demonstrated its utility as a tool for enhancing learning outcomes (McQuiggan). Information delivered in story form improves recall of that information, and emotionally arousing narratives improve recall further (McGaugh). Narrative is so closely related to memory that some have asserted that memory effectively *is* narrative - that human memories are stored, indexed and accessed as stories (Schank).

Beyond the established engagement and memory enhancements effects of narrative, narrative also allows video to function as a container for multiple visualizations that cover a theoretically unlimited number datasets. It gives video the capability to connect those datasets and describe the relationships between them. Video narratives can also bring non-numerical contextual information to datasets, further increasing the density of data-driven stories.
Visualization and Digital Filmmaking

Narrative, guiding, and other forms of temporal stratification can take video visualizations off the static page and begin to exploit the media-specific characteristics of video. But video has more resources available for exploitation. In a hypothetical media specificity analysis of film and literature, Stam makes the following observation about cinema being valuable as a composite of other mediums:

“...it could just as easily be argued that cinema, precisely because of its heterogeneous manner of expression, is capable of greater complexity and subtlety that literature. Cinema's audiovisual nature and its five tracks authorize an infinitely richer combinatoire of syntactic and semantic possibilities. The cinema has extremely varied resources, even if some of those resources are rarely used (just as some of the resources of literature are rarely used). Film forms an ideal site for the orchestration of multiple genres, narrational systems, and forms of writing. Most striking is the high density of information available to the cinema.” (Stam 45)

Wealth Inequality in America is an example of a digital short film that uses good 2-D design practices, and adopts a many of video's time-based conventions this paper advocates (narrative, cueing etc.). But there are few indications that the film has wholly abandoned a static design paradigm in favor of a digital filmmaking paradigm. Despite several cueing devices, narration and some movement, the backdrop is unchanging and the viewing experience is, for the most part, static. Charts, although cleverly animated, are swapped in and out as if flipping pages of a book. The soundtrack is limited almost entirely to voiceover narration and a subtle music track. Wealth Inequality in America is an example of quality information design to be sure (Tufte would likely approve), but it
embraces only a few of the “varied resources” of video, and thus does not escape the motion picture equivalent of flatland.

**Case Study: Leaded Gasoline and Crime**

In my short film, *Criminal Element*, I attempt to create a data visualization video that escapes video flatland. I employ many of the traditional 2-D information design strategies discussed in the second chapter of this paper, while embracing a digital filmmaking paradigm.

The film tells the story of the connection between the rise and fall of violent crime rates in the United States from 1960-2000 and leaded auto fuel. Lead (specifically the compound Tetraethyllead) is an antiknock agent and performance boosting additive mixed into virtually all American gasoline starting in the 1920's. It remained a component of gasoline until the early 1970's. In the last decade, statisticians have found a strong link between the rise and fall of leaded gasoline's use in the United States, and the rise in violent crime rates about twenty years later. The connection is further supported by studies that link childhood lead exposure to sluggish brain development, delinquent behavior, and long term loss of intelligence.

The story is hugely multivariate – data supporting the connection includes time series' of national state and city crime rates, leaded gasoline consumption, atmospheric lead levels, blood lead levels, and data from a corpus of medical studies correlating lead in the human body to specific physiological and psychological problems.
It is possible that a collection of static graphics, could tell this story in sufficient detail to enable viewers to understand the connection. But a composite narrative medium such as video can offer greater contextualization of these numbers. It can answer important questions that charts alone may not be able to. Why was there lead in gasoline in the first place? How did that lead end up in peoples' bodies and why did it increase the likelihood they would exhibit criminal behavior? Well-designed charts can tell us a lot about what happened, but they fail to string together the deeper connections that make the story richer, more meaningful, more engaging, and more memorable. The story connecting leaded gasoline and crime is a story that seems to demand narrative.

In *Criminal Element*, I attempt to visualize and contextualize the data relevant to the connection between leaded gasoline and crime. The data presented in the film comes from a handful of published economic and medical papers. My first task was to study this body of literature and decide which datasets were most relevant, which weren't, and which best fit into a coherent narrative. An overabundance of data was available, so prioritizing data was a critical first step.

After deciding what data to include in the film, the next step was to design visualizations appropriate for that data, keeping in mind all the strategies discussed in this paper. The fleeting nature of video meant relying on established graphical representations of data, in short: bar and line graphs. The data supporting the story did not call for novelty in individual visualizations, and the pace of the story did not allow time for teaching viewers how to read such visualizations. I was able to innovate, however, in the attention cuing and other temporal stratification methods I used to retain
density and clarity without overwhelming viewers. For instance, gridlines for several charts appear only for a short time. This establishes them as a backdrop for the graphic, but their disappearance quickly diminishes clutter and allows the data and the trends they show to remain the focus of the graphic. I also stratified labels over time in order to prevent high the visual search and accompanying cognitive overload associated with seeing a large number of text labels at once.

With the visualizations in place, I then structured the narrative to best incorporate the interconnected datasets and their visualizations, and to take advantage of the inherent drama in the data. The first task was to identify the most appropriate entry point to a story that spans a half-century. The precipitous, and once mysterious drop in national crime rates seemed to be a natural place to begin the story. The mystery provided drama and is presumably the motivation that drove statisticians and economists to study the topic. Using other dramatic points in the story and other contextualizing information, such as the rise in automobile sales resulting from the end of World War II, was also critical to the design of the narrative.

Finally, I used additional video-specific resources in order to further enhance the emotional arousal of the film. Through drama in narration, photographs, editing, and music, I attempted to make the film more engaging and more memorable.

There are thousands of data-driven stories like the story told in Criminal Element. Most of those stories are found in papers and studies that are of limited use to those uninitiated in the research fields from which they originate. Such papers and studies are dense with data, but also filled with nuance and contextualization. My hope is that
Criminal Element can serve as a model for other visualization designers, digital filmmakers and storytellers who wish to tell similar data-dense stories in an accessible format, while retaining that nuance and context.
REFERENCES CITED


