CHAPTER 2

Storytelling in the Wild

Implications for Data Storytelling

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CONTENTS

Everyone, everywhere seems to love stories. The smallest of people can be gripped by stories, even stories they don't completely understand. What accounts for their power? So many things. An easy answer: stories are life, in all its richness. But that will not do. Stories have both more than life and less than life, and are all too frequently more engrossing than life. Stories have all the elements of life, and then some: People, place, time, emotion, intention, causality, drama, suspense, mystery, and then, lurking beneath for readers to discover and rediscover, morals, magic, and meanings of all kinds in every layer. Like life, but life condensed, sharpened, embellished, and reimagined. Stories give meaning to our lives, they interpret our lives, perhaps the reason we, singly or collectively, constantly tell and retell the stories of our lives. A recent engrossing history of humankind, *Sapiens* (Harari, 2014), concluded: it is all stories.

Crafting good stories is not easy. Small children have to learn to tell them, to learn that stories are not just *and then*, *and then*, *and then*, one thing after another. How stories are condensed and sharpened and embellished and reimagined is key to their magic. Stories—good ones—are at once both unique and universal. Stories can make the familiar strange and the strange familiar (Bruner, 1987). They draw us in through the particulars and lead us out to the general. The best of stories can reach a multitude through an individual, from the personal to the collective. Herein lies the first tension between storytelling and data. Stories are about individuals and data are about generalities.

We spend endless hours crafting and recrafting stories from our own lives (cf., Bruner, 1987; Marsh & Tversky, 2004), and endless hours watching, hearing, or reading the stories of others. We can hear so many more stories than we can experience. They expand our narrow window on the world. We can see ourselves or others in them and pull insights and life lessons from them. Stories have layers of meaning, and from understanding them we can learn how to find meaning in our lives and how to live our lives meaningfully. Stories, like our lives, can be endlessly interpreted and reinterpreted.

Data, on the other hand, seem to be the antithesis of stories. If stories have people in all their richness, data have points, rich meanings reduced to numbers. If people are ambiguous, changeable, and ineffable, data are certain, static, and clear. People have desires and conflicts and ambitions and emotions; they have successes and failures; they can be inspiring or abhorrent. Data have none of that. For some of us, the readers of this chapter, data of all kinds are exciting and meaningful, an invitation to explore and to think. Yet even we, those of us inspired by data, need the data to be presented in ways that invite exploration and thought. But for many intelligent and thoughtful people, data elicit eyes glazed over no matter how they are displayed. The more reason to weave them into good stories.

Like all good words, *story* is used by many communities with many senses. There are bedtime stories and stories in novels that are typically pure fantasy; there are the stories we tell each other about our lives that are meant to bear some semblance to truth but that are filtered through our narrative voice and point of view; there are newspaper or journalism stories that are about actual events and supposed to be free of a particular narrative voice or a specific point of view; and there are the stories of politicians often called *spin*, the stories governments and companies tell to get your trust. Just as *story* is used differently in different communities, it will be nuanced differently here, consistent with the immediate larger context. So do not expect consistency in the use of the term. No one community has ownership. One rather widely accepted sense of story will be developed below to draw distinctions with contrasting forms of discourse, notably descriptions and explanations.

PREVIEW

Before there are stories, there are the events that give rise to them, and that is where we begin, with *event perception and comprehension*.

When people view ongoing continuous events, simplified ones that can be brought into the laboratory, they segment them hierarchically. The breakpoints between event segments are identified by large changes in the physical stream that signal changes in actions, intentions, and goals. From perceiving events to *retellings of events*, the spontaneous stories of our lives that we tell our friends. Retellings embellish by adding, omitting, and exaggerating even important details; fortunately, many of these are discounted by listeners. After that, to the *kinds of discourse*, primarily *description*, *explanation*, *storytelling* (but also *argument*, *journalism*, and *conversation*) and an integrative form, *narrative nonfiction*. Briefly, descriptions present the appearance and structure of people, places, things, and events organized appropriately; explanations add causality; and stories may add features like a narrative voice, protagonists and antagonists, emotion, suspense, and more. Narrative nonfiction is a form that weaves together stories, descriptions and explanations, the individual and the general, the specific and the abstract, dramatically and rhythmically. Next, *visual storytelling*, ancient and modern, noting both the expressed ideas, space, time, people, animals, and objects, and how they abstracted, depicted, and connected. From there to an analysis of how graphics work: they use space and elements in it to represent a multitude of concepts, concrete and abstract, and their interrelations. That analysis leads naturally to a discussion of empirical methods for uncovering cognitive design principles for effective graphics for various domains. Afterwards, I draw insights from *comix*, a term invented by Spiegelman (2013) to describe the inventive history of combining words, depictions, and more to tell stories. Then I take a glance at gestures and a peek at the design of the world, showing how each communicates abstract thought.

Stories can be interesting in and of themselves, but stories, especially those crafted around data, are important also for what we infer, remember, and learn from them and how they affect our actions. "We" includes many audiences who read for diverse reasons. Moreover, stories can be told using diverse media. It goes without saying that designing stories around data has to take into account the background of the audience as well as the goals, qualities, and constraints of the media.

PERCEIVING AND UNDERSTANDING EVENTS

First comes the experiencing, then the telling. Caveat: not always. For one thing, there is the planning. And the directing. Understanding how people perceive and understand events has implications for how news stories should be crafted, what to include—goals, intentions, causes—and where to cut.

Events do not arrive neatly boxed and labeled. We do that ourselves. Events arrive as a continuously fluctuating multimodal onslaught to all our senses, James' blooming buzzing confusion (James, 1890). Some of it relevant, most not. We make sense of that ever-changing diverse stream by packaging it into discrete chunks, the categories central to our existence: faces, bodies, objects, scenes, and events, categories that are so central that language is brimming with words for them, and, save events, that the brain has specialized areas for processing them. And then to interpretations, emotions, reasons, causes, and consequences. Events take place over time, unique in that set of fundamental categories. Events stretch from quotidian ones like making a bed or doing the dishes, to epic ones like weddings, revolutions, and recessions.

How do we perceive and understand events? Several fundamental questions arise, many analogous to questions addressed in the perception and cognition of objects and scenes (cf., Tversky, Zacks, & Hard, 2008). Like objects and scenes, events have both a taxonomic structure—*kinds* of objects, scenes, and events—and a partonomic structure—*parts* of objects, scenes, and events. How do we segment events into parts? It is easier to bring the quotidian events into the laboratory to study, and many of the findings undoubtedly generalize.

In what has become a standard paradigm for studying event perception and cognition, participants view videos of familiar everyday events like making a bed or doing the dishes (e. g., Newtson, 1973; Newtson & Engquist, 1976; Newtson, Engquist, & Bois, 1977; Newtson, Hairfield, Bloomingdale, & Cutino, 1987). They are asked to press a button every time, in their judgment, one event segment ends and another begins (e.g., Hard, Recchia, & Tversky, 2011; Kurby & Zacks, 2007; Tversky & Zacks, 2013; Tversky, Zacks & Hard, 2008; Zacks, Speer, Swallow, Braver, & Reynolds, 2007; Zacks, & Tversky, 2001; Zacks, Tversky, & Iyer, 2001).

On the whole, people agree on the temporal locations of segment boundaries, referred to as *breakpoints*. When asked to segment twice, at the highest level that makes sense and at the lowest level that makes sense, people's segmentation was hierarchical, that is, the fine-level events fit nicely into the coarse-level boundaries. When asked to give play-by-play accounts of what happened in each segment as they segmented, people reported a sequence of actions on objects and completions of goals and subgoals. The higher or coarse level was segmented by different objects or object parts and the lower or fine level by different actions on the same object. Think of making a bed. The coarse-level actions were described by one participant as, "taking apart the bed; putting on the bottom sheet; putting on the other sheet; putting on the blanket…." Each new coarse-action segment involved a new object. The same participant described the fine-level actions in this way: "unfolding sheet; laying it down; putting on the top end of the sheet; putting on the bottom; straightening it out." Each new fine-action segment involved a new action on the same object.

Although these were familiar and brief events, the kind that can be completed in a few minutes and filmed from a stationary camera, a naturalistic study observing behavior in the real world found similar results. In that study, coders recorded what people in a small town were doing, day after day. Observers segmented when there was a change in person, place, object, or action (Barker, 1963; Barker & Wright, 1954). Although the events in these studies were performed by humans, not natural events like eclipses, hurricanes, or earthquakes, the latter are also perceived to have a sequence of steps associated with causes (e. g., Buehner & Cheng, 2005).

Breakpoints are privileged, marking the convergence of many cognitive and perceptual measures as well as an objective change in the sensory input, a convenient and nonaccidental concurrence. Local maxima of change in the physical stream occur at breakpoints, larger for coarse than fine breakpoints (Hard, Reccia, & Tversky, 2011; Hard, Tversky, & Lang, 2006) indicating that more is changing at breakpoints than at ordinary moments. Correspondingly, people look longer at breakpoints (Hard et al., 2011) and relevant brain activity rises at breakpoints (Speer, Zacks, & Reynolds, 2007; Zacks, Speer, & Reynolds, 2009). People understand and remember a sequence of stills composed of breakpoints better than a sequence of stills that are not breakpoints (Newtson & Engquist, 1976; Schwan & Garsoffky, 2004). Scrutiny of breakpoints reveals that they are transition points; moments where actors simultaneously complete one action and began another. Think of making a sandwich. As you are finishing spreading butter on one slice of bread, you turn your head and body to find the next slice.

Breakpoints in continuous events also mark a confluence of bottom-up and top-down processes. Bottom-up processes are moments of relatively greater change in the continuous behaviors. Top-down processes are moments where goals and subgoals are completed. That event structure is reflected in both bottom-up and top-down processes, both in perception and cognition, allows making inferences from one to the other. The ebb and flow of action enables observers of unfamiliar events to infer the hierarchical structure of events and use that to bootstrap meaning (Hard et al., 2006). Conversely, knowledge of the structure of events allows anticipating greater activity at event boundaries.

Although events are experienced as a linear sequence of actions and consequences, retellings of events can be quite different from experiencing the events, and we turn to that now.

SPONTANEOUS RETELLINGS OF EVENTS

People talk a lot about their lives. Storytellers want to make their stories engaging, and to do so, they select what to relate and how to relate it (Dudokovic, Marsh, & Tversky, 2004), a task shared by data storytellers. To learn how that happens in everyday life, we asked university students to record events that they retold to their friends, family, and other acquaintances over the course of 4 weeks (Marsh & Tversky, 2004). For each retelling, they wrote what had actually happened, what they had said, to whom they said it, and for what reason. They wrote whether their retelling was accurate and then whether they had omitted important details, added details that did not actually happen, or exaggerated or minimized aspects of what actually occurred.

By their own admission, participants called 42% of their retellings inaccurate. But even this understated the degree to which they misreported the events they retold. Fully 61% of their retellings were altered by exaggeration, minimization, or addition or omission of important details, again by their own admission. This suggests that a considerable degree of misrepresentation is tolerated by storytellers as "accurate." An unpublished naturalistic study revealed that some degree of misrepresentation is not only tolerated but expected by listeners. If a friend laments that he did not sleep more than 4 hours a night the entire week, you might take that to mean that he is stressed out rather than taking the hours of sleep literally.

Readers probably will not be as tolerant of the distortion of events in news reports or the presentation of data. However, readers might expect such distortions in the claims of politicians or the accounts of eyewitnesses that are often significant parts of stories in the news.

KINDS OF DISCOURSE

We begin this section with an example, perhaps the most consequential data story ever. In an email to the then graphics editor of *The New York Times*, Steve Duenes, columnist Nicholas Kristof related that Bill and Melinda Gates had changed the mission of their foundation from providing computers to third world countries to fighting disease because of columns Kristof had written in 1997 describing the severe consequences of bad water on children. What convinced the Gateses were not Kristof's words, but rather the graphic designed by Jim Perry. The graphic was simple, almost entirely text. See the mock-up below. Two columns on the left includes four diseases caused by bad water and the numbers of deaths associated with them per year. The first, diarrhea, accounted for 3,100,000 deaths per year; the other three, a total of 430,000 deaths per year. On the right column is a detailed description of the diseases. The first thing a powerful data story needs is powerful data.

Graphs, charts, and diagrams, like facts, often cannot stand on their own. They need to be embedded in some genre of discourse. Storytelling is one kind of discourse, an especially engaging form, but there are others. Even though more and more human communication is mediated, the prototypic and ancient genre is face-to-face. Face-to-face interactions are especially rich; they harmoniously blend words, prosody, gestures, and actions interactively to create meaning. Early on, people began to put thought in the world in more permanent ways, as trail markers, cave paintings, petroglyphs and

Death by Water

A huge range of diseases and parasites infect people because of contaminated water and food, and poor personal and domestic hygiene. Millions die, most of them children. Here are some of the deadliest water-related disorders.

DISORDER/ESTIMATED DEATHS PER YEAR	
DIARRHEA **3,100,000**	Diarrhea is itself not a disease but is a symptom of an underlying problem, usually the result of ingesting contaminated food or water. In children, diarrhea can cause severe, and potentially fatal, dehydration.
SCHISTOSOMIASIS **200,000**	A parasitic disease caused by any of three species of flukes called schistosomes and acquired from bathing in infested lakes and rivers. The infestation causes blooding, ulceration, and fibrosis (scar tissue formation) in the bladder, intestinal walls, and liver.
TRYPANOSOMIASIS **130,000**	A disease caused by protozoan (single-celled) parasites known as trypanosomes. In Africa, trypanosomes are spread by the tsetse fly and causes sleeping sickness. After infection, the parasite multiplies and spreads to the bloodstream, lymph nodes, heart, and, eventually, the brain.
INTESTINAL HELMINTH INFECTION **100,000**	An infestation by any species of parasitic worms. Worms are acquired by eating contaminated meat, by contact with soil, water containing worm larvae, or from soil contaminated by infected feces.

Sources: *The New York Times*, January 9, 1997; World Health Organization; *American Medical Association Encyclopedia of Medicine*.

such, preserving the visual-spatial aspects of communication carried by a joint presence in the world, but eliminating interactivities, gestures, prosody, and words. Later, written language represented word meanings. The advent of pixels allows forging the visual-spatial and the verbal back together in fluent harmony, and that forging is key to effective data storytelling.

Communication is structured at many levels, not only the familiar syntactic, semantic, and pragmatic, but also at the more encompassing level of discourse, here referred to as *genre.* Genre reflects the mode of conveyance, primarily description, explanation, or story. Many communities have analyzed genres of discourse—linguistics, literature, rhetoric, journalism, comics, drama, filmmaking, animation, narratology, law, philosophy, sociology, psychology, and more (some, but far from enough, resources for psychology and stories: Bruner, 1987; Bower, Black, & Turner, 1979; Brewer & Lichtenstein, 1982; Mandler, 1981; Rumelhart, 1975; Trabasso, Stein, & Johnson, 1981; psychology, conversation: Clark, 1996; psychology, film: Cutting, DeLong, & Nothelfer, 2010; Magliano, Miller, & Zwaan, 2001; Zacks, 2015; film: Bordwell & Thompson, 2003; Brannigan, 1992; Murch, 2001; Tan, 1996; linguistics, discourse: Brown & Yule, 1983, Gee, 2014, Ronen, 1990, Shiffrin, Tannen, & Hamilton, 2008; Van Dijk, 1993, 2001; linguistics, stories: Chafe, 1980, 1998; computer graphics: Hullman & Diakopoulos, 2011, Hullman, Drucker, Riche, Lee, Fisher, & Adar, 2013; Segal & Heer, 2010; comics, graphic narratives: Eisner, 1985; McCloud, 1994; narratology: Bruner, 1987; Prince, 2003; philosophy, Currie, 2010).

These communities have different aims and methods and produce different analyses. It is not feasible to review that work here. Instead, I present an analysis of the core genres of discourse that seem relevant here based on portions of the vast literatures.

Each genre can be expressed in words or graphics, or ideally, a combination of both, complementing each other and doing what each does best. There is an important point here. Pure words are meant to be read in order, and often are. Graphics typically do not demand or even guide an order of taking in the information. The absence of a guiding order can be confusing to some readers, doubly confusing when words and graphics are combined, and triply when interactive. How much to guide a reader and how to do that are important design considerations.

Of the core genres of discourse, three, *description*, *explanation*, and *story*, are the most central; and to these I add three more specialized but relevant forms, *argument*, *journalism*, and *conversation*. I have no doubt that experts in the various fields might take issue with some distinctions as well as also with each other. As I structure the first three forms, each adds elements to the previous form so that they build on one another. I end the section with a discussion of literary journalism, or literary nonfiction, the genre that seems most pertinent to current nonfiction including data storytelling, a form that weaves together the discourse types rhythmically.

Whether genres are pure or mixed, words or graphics, ordered or not, every piece of discourse requires authors to select the information that is relevant, to express it felicitously, and to link the pieces into a whole. An elementary decision for authors is whether to impose an order, canonical for purely verbal media, or to create interactivity, allowing readers to explore. When ordered, as in words or words and graphics embedded in a narrative, there is a beginning, middle, and end. The beginning serves as an entryway or introduction. The middle consists of a compelling sequence of related assertions. Note here the tension between surprise and drama on the one hand and continuity and clarity on the other. Jumping to a new topic without a segue might baffle readers, but also involves them, creating a mystery they are invited to solve. The end draws together and concludes a set of ideas in a meaningful way. Creativity is needed throughout. Beginnings should intrigue readers to draw them in. Beginnings may also establish expectations about the rest of the discourse, providing rubrics or drawers for organizing what follows. Endings should at the same time tie things together with a kick and leave readers with much to ponder.

Description

A representation of the appearance and/or structure of a person, thing, space, event, or state of affairs. Each of these can use words, graphics, or both. Photos and sketches can be apt for people, places, things; so can maps, charts, and diagrams. Events can be conveyed by timelines, storyboards, step-by-step diagrams, animations/simulations, comix, and more. If in words, the order of telling is typically driven by the content described, for example, a hierarchy of importance, beginning with salient or general features and proceeding into greater detail. When describing a space or environment, people typically begin with an overview or with an entrance (e.g., Taylor & Tversky, 1992).

Explanation

Provides an interrelated set of reasons, typically causes or justifications, for some state of affairs. The order of telling is typically driven by the temporal or causal structure and the end is typically the outcome of the process. Timelines, flowcharts, step-by-step diagrams, storyboards/comix are especially appropriate graphics for explanations. Animations must be designed with care for several reasons. People often understand and explain events over time as sequences of discrete steps, not as continuous unsegmented action. Animations all too often present too much too quickly for viewers to comprehend. Finally, animations must explain, not simply show (Tversky, Morrison, & Betrancourt, 2002).

Stories

Typically (but not necessarily) add characters, a narrative voice, problems and resolutions, motives, intentions, emotions, suspense, and drama. Although stories typically have a temporal, indeed causal, order, they are often told in other orders to create suspense or mystery to draw readers in. Following the Russian formalists and then the French structuralists, it is common to distinguish the actual events (*fabula*) from the way the events are structured in the narrative (*syuzhet*) (cf., Bruner, 1985). Another important point—the same sequence of events, the core of a story, can be arranged in many ways; doing so serves as warm-up exercises for storytellers of all kinds (e.g., Madden, 2005; Queneau, 1947). Some arrangements will be better than others, but like wine, paintings, and lovers, which versions are best is a matter of taste.

People love to find patterns and classify, and stories are no exception. Authors of how-to guides classify story types, claiming various numbers and types of basic plots, 1, 3, 7, 20, 36, and undoubtedly more. There are the timeless plots, the stuff of myths, Greek tragedies, soap operas, scriptures, Shakespeare, *Star Wars*, and *Harry Potter*: pride before a fall; quest—for love, fame, fortune, enlightenment, power; coming of age; crime and punishment; remorse and salvation; frog into prince; hero overcomes tyrant. They have morals and life lessons: persevere and you will succeed; good triumphs over evil; love lost is better lost; appearances can be deceiving. Some of the themes are contradictory, keeping readers in suspense; if the hero gets in trouble, you do not know if his or her hubris will lead to a fall or if his or her persistence will lead to success. Stories have rhythms: the classic Aristotelean triangle of slowly rising action to crisis, followed by release and resolution. Briefer rhythms on the way: problems encountered and resolved.

Adding graphics and basing stories in data rather than individuals complicates matters of selection, expression, arranging, interactivity, mode, and genre. Recent surveys of data-telling stories have analyzed the categories that authors seem to have used. Considering formats, Segal and Heer (2010) distinguished: magazine styles, annotated charts, partitioned posters, flowcharts, comic strips, slide shows, and film/video/animations. They took note of graphic narrative devices that introduce (overview establishing shot), direct attention (e.g., grouping, arrows), and maintain orientation (e.g., visual anaphora, slider bar) as a narrative proceeds. Hullman and Diakopoulos (2011) survey a large number of illuminating examples that illustrate rhetorical devices adopted in data storytelling. Hullman et al. (2013) examined the kinds and frequency of transitions in data videos, relating them to techniques used in film. Not surprising, the most frequent transition was chronological, appropriate for descriptions and explanations; the second was general to specific, appropriate for descriptions.

Descriptions, explanations, and stories provide mental models that help us to understand the world: descriptions for the appearance and structures of organisms, things, places, and institutions; explanations for how things, people, nations, systems operate and work; stories for all forms and interactions of humanity, emotion, ambition, and desire.

Three additional forms of discourse that fit sideways rather than building on the previous are discussed below.

Argument

An argument is similar to an explanation in providing reasons, causes, or justifications. Presumably called an argument rather than an explanation because the reasons, causes, or justifications may be open to debate and/or because arguments may provide reasons, causes, or justifications for what might happen or should be.

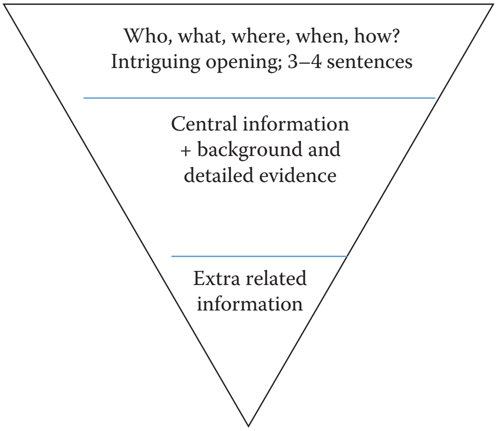
Journalism

True events that are newsworthy. The critical information is: who, what, where, when, why, and how. Told first succinctly, then in more detail, and then again with related detail, represented by the emblematic inverted triangle. This triangle is a static one representing the structure of an article, from top to bottom.

Interestingly, the journalism triangle more or less corresponds to the mantra of interactive graphics: overview first, zoom and filter, and details on demand (Shneiderman, 1996).

Conversation

Conversation is interactive. Two or more participants, each making contributions, typically brief and in alternation, that build on each other. The



contributions can be descriptions, explanations, arguments, stories, or other. The participants do not have to be human or use words.

Although the elements of descriptions, explanations, stories, and conversations differ, in actual practice, the genres are usually mixed. Explanations typically include descriptions and stories usually include both, and arguments, journalism, and conversations can include all. This brings us to a genre known variously as literary nonfiction, literary journalism, or creative nonfiction (e. g., Buell, 1980; McPhee, 2013; Sims, 1984; Sims & Kramer, 1995; Winterowd, 1990). In today's lingo this genre would be called disruptive as it violates chronological or causal order. It borrows from literature and implicitly from music and sermons, creating the drama, suspense, variety, and change of pace to keep readers reading. It interweaves the specific and the abstract, the particular and the general, in a spiral of changing rhythm.

Implicit throughout this volume is the assumption that data journalism will be experienced on a screen or in print. As if that were not enough, virtual reality (VR), augmented reality (AR), and situated visualizations are providing exciting new ways for people to experience data stories along with new design challenges.

GRAPHIC DESCRIPTIONS, EXPLANATIONS, AND STORYTELLING

There are many concepts that are difficult if not impossible to express visually, like *truth*, *faith*, and counterfactuals, but there many others that are expressed more directly in depictions than in language: faces, places, animals, objects, and shapes among them, as well as spaces, as in maps, events, behavior, processes, and more. We quickly run out of words that can distinguish one face from hundreds of others. Intricate actions and subtle emotions are so often better expressed by face and body than by words. Similarly, for more abstract information: line graphs showing changes in population over time, flow of water or electricity, chemical bonding, or mechanics of, for example, car brakes. As the billions of consumers of graphic novels, film, and video know, visual stories can be especially powerful, captivating, and memorable. More and more, media combine both words and images. But storytelling began as depictions long before there were written languages.

Ancient Graphics

Graphic representations are ancient, long preceding written language. Frequent topics were beings and things, space, time, and number. Vivid images of animals, singly, in groups, and in stampedes, remarkably still adorn the walls of the Chauvet caves in the south of France, even though they were painted at least 35,000 years ago. Animals, along with handprints and more rarely, people, appear on walls of ancient caves and surfaces of petroglyphs all over the world. Ancient maps, those that survived, typically mixed perspectives with overviews of paths and rivers and frontal views of landmarks, buildings, mountains, and the like. Maps of heavenly bodies appear in ancient times and even earlier, and situated visualizations like sundials and Stonehenge and Mayan temples that were carefully aligned with paths of celestial bodies. Processions of images painted on the walls of Egyptian tombs more than 3000 years ago show events in time step-by-step: how to grow and harvest wheat and make bread or how to make bricks (Smith & Simpson, 1998). Time was visualized more abstractly in calendars, often circular. Ancient tallies inscribed in bones or stone have been discovered in remote parts of the world dating back more than 35,000 years. Some seemed to have been used for accounting, others for astrological recording (Pickover, 2009). In fact, writing is regarded to have begun for accounting, that is, for keeping track of data—the sizes of herds of cattle and sheep for taxation (Schmandt-Besserat, 1992). Ancient mandalas and friezes scattered across the eastern world show the panoply of Buddhist and Hindu gods. Aztec and Maya codices depicted their unfolding history, often superimposed on a map (Hassig, 2001; Sharer & Traxler, 2006). Greek and Etruscan vases, mosaics, friezes, and frescoes illustrate their myths and histories. As for many ancient depictions, relative sizes and positions often do not reflect actual size or position; instead, they have symbolic meanings, reflecting power or social rankings (Small, 2015).

These marvelous and varied remnants of ancient cultures appear to intend to show, describe, record, explain, and inspire. They depict concrete things, people, animals, and tools; they portray things in space and show events in time; they represent numbers for various uses; and some seem to be purely spiritual.

Modern Graphics

Intriguingly, graphics that do more than show or summarize observable entities and events are nearly absent before the late 18th century. William Playfair in Scotland and Johann Heinrich Lambert in Switzerland (Beninger & Robyn, 1978; Spence, 2000) are credited for developing the first displays of data, line graphs showing changes in some value, usually economic, over time. It is probably the most common data visualization to this day. At that time, diverse scientists and engineers invented new ways of abstracting and depicting data and processes (see http://www.datavis.ca/milestones/index.php?group=1700s, a website developed and maintained by Michael Friendly and Daniel J. Denis). These visualizations became tools of thought and inference for scientists and policy makers alike. Their appearance not only coincided with advances in science and technology, but spurred those advances. The science and technology and the visualization of science, technology, and data leapfrogged each other, a virtuous cycle that continues—think, for example, of Feynman diagrams, cloud chambers, the Hubble telescope, the tunneling microscope, and the double helix. Modern graphics include displays of data and diagrams of mechanical, astronomical, anatomical, and other scientific processes, many of which are not directly observable.

Unlike ancient graphics, modern ones use words and symbols as well as visual-spatial representations of information. The use of words in visualizations is quite different from their use in text. In graphics, the visuals are primary, the words annotated. Words do not appear in sentences; they are used to label, augment, and clarify the visual information. Similarly, numbers and symbols are incorporated into graphics.

Information diagrams began to appear in abundance in the same era, perhaps promoted by the publication and popularity of Diderot and D'Alembert's *Encyclopedie* (1751/1772) (see Figure 2.1). Purporting to be a compendium of all accumulated human knowledge in the sciences, arts,

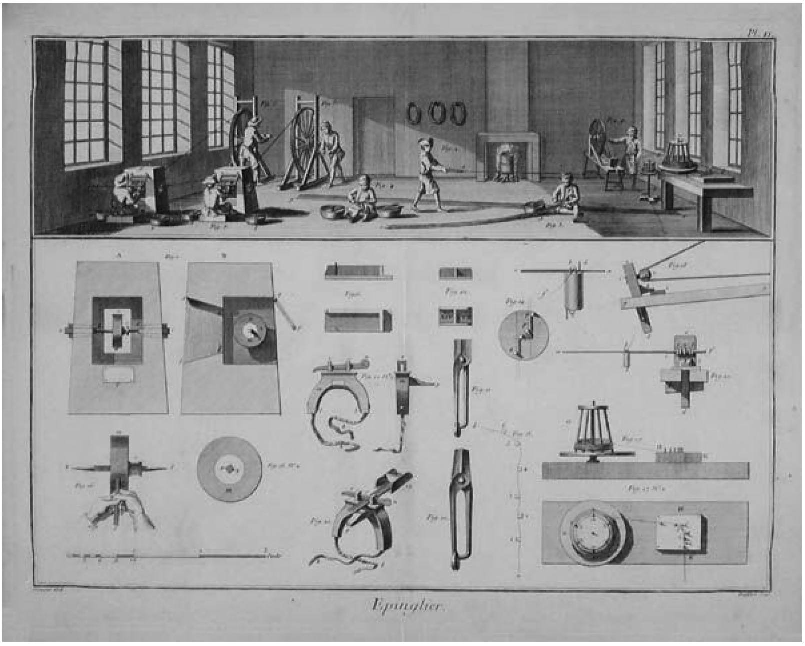


FIGURE 2.1 The pin factory plate from the Encyclopedie of Diderot and D'Alembert.

Source: **https://commons.wikimedia.org/wiki/File:1762_Diderot%27s_Encyclopedie,_Epinglier_II.jpg.**

and industry, the encyclopedia opened with a conceptual diagram, a tree of knowledge divided into memory, reason, and imagination. The 28 volumes with over 70,000 articles written by diverse contributors contain over 3000 diagrams. Many of the diagrams have the same format, a format that teaches readers what a diagram is. There are two halves, each enclosed in a box. The boxes are containers and separators: they contain one kind of information display and separate that kind from the other kind. The top halves depict a natural scene, typically an industry workshop of some sort—dressmaker, beekeeper, glassmaker—with workers using the instruments of their trade. The scene is caught in action; the people holding the instruments they use proportional to their actual sizes and in the appropriate places and positions, and the light and shadows determined by the light coming from the windows. Scenes would have been familiar to readers at the time, but the format of the information display in the bottom half would have been novel. The bottom halves show only the tools and instruments of the trade. They are arranged like a catalog in rows and columns, grouped by related functions. Their image sizes are more or less equal, not proportional to their actual sizes. Their orientations and shading are devised to enhance their 3-dimensional (3-D) structure, not to reflect ambient lighting. Both parts are enclosed in a larger box, separating the diagram from the surrounding text. It is as if the diagram is telling you that it is a diagram as well as teaching you what a diagram is. A diagram was a new form of representing information, in contrast to a familiar form, a depicted scene. Diagrams do more than depict; as Bender and Marrinan (2010) note, they are meant to be "worked with"; that is, studied for inference and understanding.

Other influential visualizations in the 19th and early 20th centuries that were meant to be worked with include Snow's map of cholera cases in London (see Figure 2.2), Minard's visualization of Napoleon's unsuccessful campaign against Russia (see Figure 2.3), Nightingale's rose (circular histogram) diagram of the causes of mortality in the Crimean War

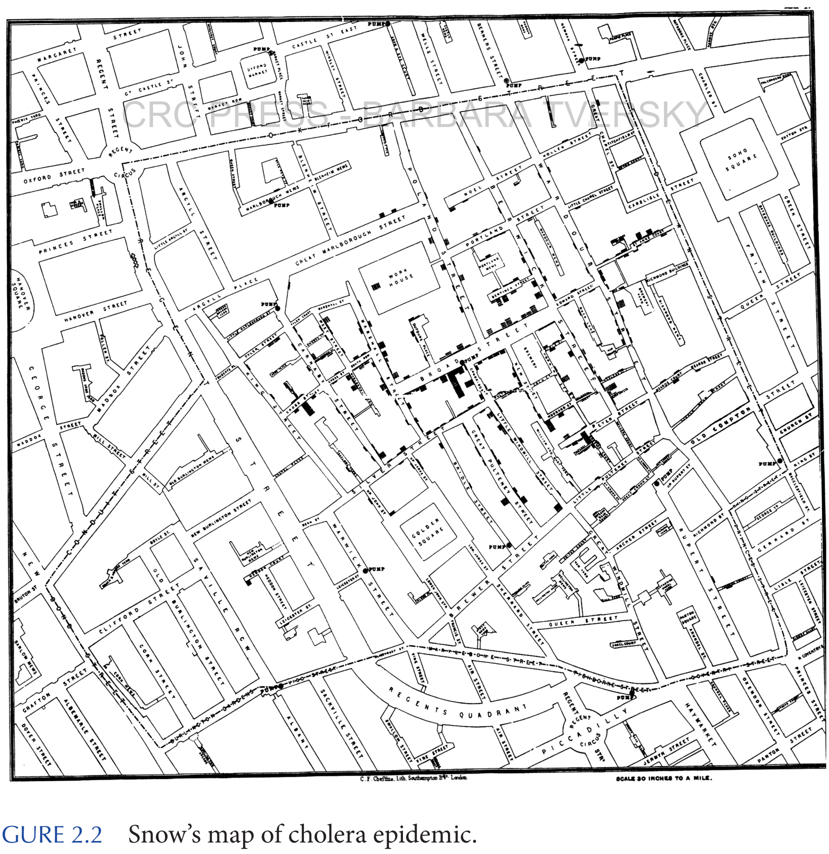


FIGURE 2.2 Snow's map of cholera epidemic.

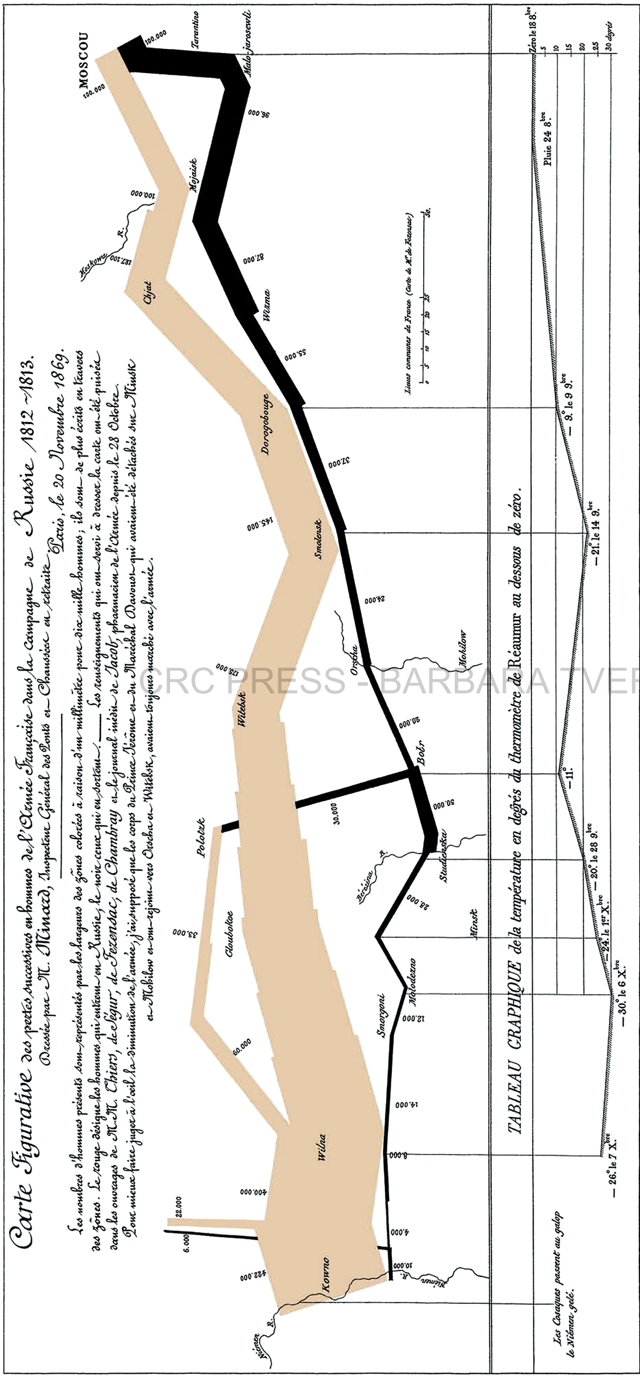


FIGURE 2.3 Minard's diagram of Napoleon's campaign against Russia.

Source: **https://en.wikipedia.org/wiki/File:Minard.png.**

(see Figure 2.4). Snow's map showing a cluster of cases of cholera at the Broad St. pump in London supported the inference to remove the handle of the pump; this led to the abatement of the epidemic, even prior to the germ theory of disease. Displaying cases on a map is in wide use today in analyzing epidemics, migration patterns, voting patterns, and more (see Figure 2.2). Minard's visualization of Napoleon's campaign used diagrammatic space with several different meanings: to represent geographic space, to represent movement in geographic space, to represent the size of troops, and to represent temperature (see Figure 2.3). Artful design prevents confusion in interpretation. Nightingale's visualization vividly showed the surprising finding that more far more military deaths were due to disease than to battle (see Figure 2.4).

The Vienna Circle, a group of philosophers, logicians, and scientists active in pre-WWII Vienna, was devoted to universals of science and accessibility of ideas; part of that concern was expressed in developing Esperanto as well as pictorial expressions of meaning, including picture languages and isotypes for data. Isotypes were developed by Otto Neurath (1936). An icon, for example, a sack of wheat or a factory represented a specific quantity of the corresponding item. The icons were arranged in rows or columns like bar graphs (see Figure 2.5).

Contemporary Graphics

The explosion of creative contemporary graphics has been exhilarating; they are everywhere. The digital age has enabled the explosion; everything is pixels, words and images, verbal representation and visual-spatial representation are conjoined, just as words and gestures are conjoined in face-to-face communication. Especially important for the current discussion are developments in graphic instructions, explanations, infographics, and comics/comix/graphic novels which now extend beyond fiction to nonfiction, science, journalism, Ph.D. dissertations, and much more. Inspiring innovations will continue to appear, making it impossible to collect a comprehensive list. At the same time, VR and AR are already producing inventive ways to visualize information and promising even more exciting developments (much is on websites; here are a few of the many print resources: Bertin, 1981; Card, Mackinlay & Shneiderman, 1999; Cleveland, 1985, 1993; Few, 2012, 2013; Fry, 2007; Heer & Shneiderman, 2012; Kosslyn, 2006; Larkin & Simon, 1987; McCloud, 1994; Munzner 2014; Tufte, 1983, 1990, 1997; Viegas & Wattenberg, 2007; Ware, 2013).

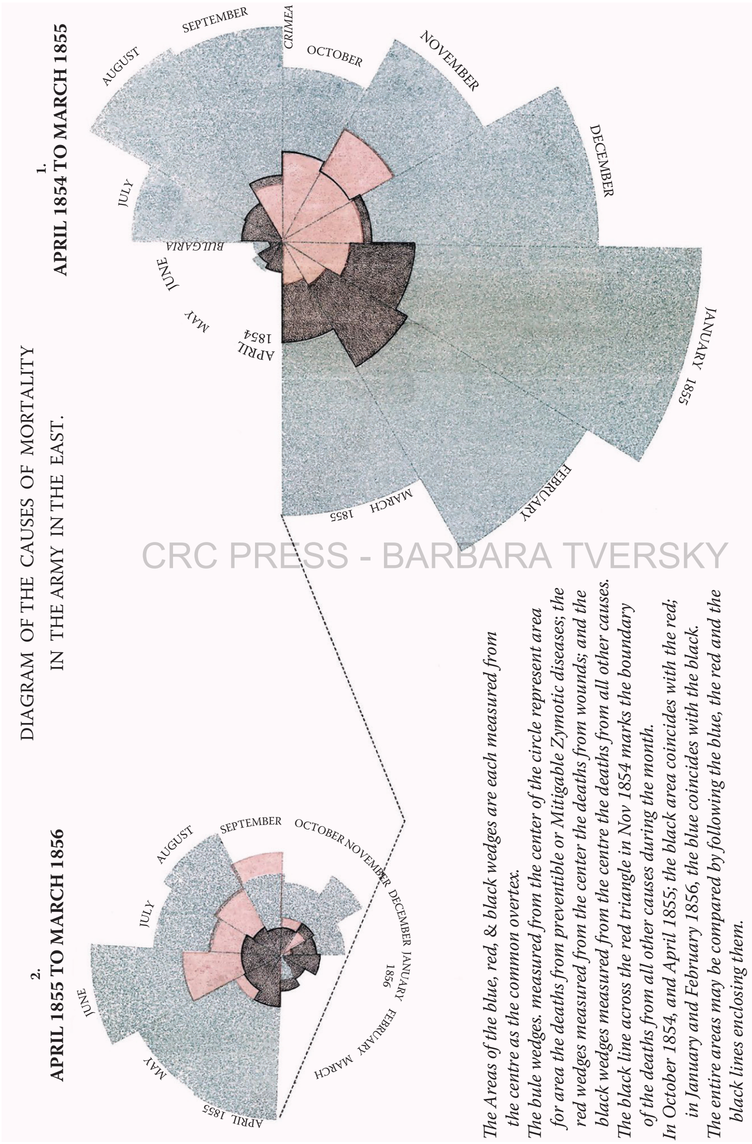


FIGURE 2.4 Nightingale's rose of Crimean War causalities.

Source: **https://commons.wikimedia.org/wiki/File:Nightingale-mortality.jpg.**

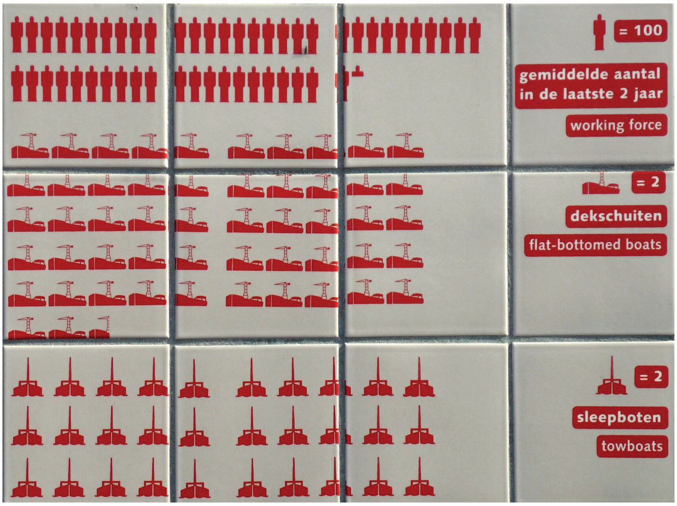


FIGURE 2.5 Neurath Isotypes.

Source: **https://commons.wikimedia.org/wiki/File:Isotype-neurath.jpg.**

HOW GRAPHICS WORK

Graphics of all kinds—maps, diagrams, charts, graphs, and sketches—use marks and places in space to convey meanings more directly than words. These meanings are carried in gestures, the precursors of graphics. In fact, much can be learned for designing effective graphics from eliciting gestures. The analysis presented here is taken from previous works (expanded in Tversky, 2011a, b; 2015; Tversky & Kessell, 2014). It might seem audacious to claim that the uses of space and marks are used and interpreted meaningfully, but each claim is supported by data, some historic, some from current best practices, or some from empirical research.

Space

There are three core ways that places in space are used meaningfully—proximity, centrality, and direction. These uses can be regarded as design principles. First, proximity in space represents proximity on any dimension. Proximity is, of course, a fundamental Gestalt principle of spatial organization (e.g., Hochberg, 2014). Things more related on any dimension are closer in space; conversely, things that are closer spatially will be interpreted as more related conceptually. This is most emphatically exemplified in maps. Proximity is not only natural in many cases, like maps, but is also a design principle for any visualization; and, for that matter, any communication: put spatially together information that is conceptually close (e.g., Larkin & Simon, 1987). A corollary of proximity is grouping: things that are grouped together are more similar to each other than things in other groups. Grouping provides a basis for categories and hierarchies. Members of well-defined groups are treated as equivalent on some dimension or attribute.

The next design principle is *place* where the center and periphery represent their metaphoric selves.

The third design principle is *direction*. The vertical dimension is powerful, and indeed represents power. Going up entails overcoming gravity; that requires resources: age, strength, health, power, and money. Hence, all good (or desirable) things tend to go up. This is reflected in language—she is at the top of the heap or he falls into a depression. It is also reflected in gestures like *thumbs up* (or *down*) or *high five*. Many expressions and gestures differ across cultures, but because gravity is universal, the association of *up* with everything good holds around the globe. Except for economics, where unemployment and inflation are plotted upwards. There are exceptions: this is not to say that economists are perverse, but when the numbers conflict with the concepts and the numbers win, they increase upwards. The horizontal is more neutral; the world has a powerful vertical asymmetry but lacks horizontal asymmetry. However, bodies have some asymmetries. Among them, handedness and the dominant hand is associated with greater value (Casasanto, 2009). The vast majority of people are right-handed and this mapping is limited to value, and perhaps to value regarded categorically. A horizontal asymmetry with more pervasive effects comes from a cultural convention, a reading/writing order. Spontaneously generated increases in almost any variable, including value, correspond to a reading/writing order, especially time, a central aspect of stories, explanations, and visualizations (Schubert & Maas, 2011; Tversky, 2011a; Tversky, Kugelmass, & Winter, 1991). Combining a place in space and reading order yields two more principles. Indentation, as seen in outlines, indicating subcategories or subimportance, as does lower, as in trees or hierarchies with roots at the top.

Marks

Marks come in many varieties. They can be depictions, photos or drawings of politicians or actors, picnic tables on road signs, waste baskets on computer docks, rows of factories in isotype bar graphs, etc. Marks also include depictions of churches or campsites on maps; they include depictions that bear metaphoric relations to what they represent, a crown for a ruler, Big Ben for London, the Eiffel Tower for Paris, etc. Written languages started as depictive. Marks can be words and symbols as well, but depictions have an enormous advantage over words in accessibility to meaning, in distinctiveness, and in memory. The Gestalt principles enter here as well: similar marks indicate similar concepts; larger, more salient marks indicate more important concepts.

Meaningful Schematic Marks

More intriguing are the meanings of marks like dots, lines, blobs, and arrows. These schematic marks carry meanings that depend on their Gestalt or geometric properties and that are typically clear in contexts (and have parallels in gestures). Think of route sketch maps. Lines typically represent paths, dots typically represent places. More generally, dots represent ideas and lines the relations between ideas. Lines and dots form the basis of networks, where the dots may represent computers or friends or ideas depending on the kind of network, and the lines represent the relations between the computers, friends, or ideas. Arrows are asymmetric lines and represent asymmetric relations whether indicating a one-way street or a one-way transformation. Blobs typically represent regions, parks, or neighborhoods on maps; processing centers in representations of brains or computer systems. As regions, they can be containers of other things—the citizens of a country on a map or sets in Venn diagrams. Dots, lines, blobs, and arrows have context-dependent meanings and form a basic visual vocabulary for creating visualizations (Tversky, 2011) as well as art (Kandinsky, 1926/2013; Klee, 1953) and language (Talmy, 1983, 1988).

Inferences from Visualizations

Visualizations are meant to enable inferences and insights. Importantly, the ways that information is represented leads to different kinds of inferences. For example, lines draw the eyes. They connect disparate entities; they suggest that the instances on the line share an underlying dimension but differ in values on that dimension. Bars contain and separate; they suggest that things within a bar are similar or related and different from the things in other bars. In several experiments, the same data were presented either as bars or as line graphs. Those who saw bars interpreted the data as a discrete comparison and those who saw lines interpreted the data as trends (Zacks & Tversky, 1999).

Arrows also carry strong meanings that affect inferences from visualizations. Undergrads were asked to interpret diagrams of a bicycle pump, a car brake, or a pulley system (Heiser & Tversky, 2006). Half the diagrams had arrows, the other half did not. Diagrams without arrows were interpreted as structural, locating parts relative to one another. By contrast, diagrams with arrows were interpreted as functional, presenting the sequence of actions and outcomes from beginning to end. The arrows changed the meanings of the diagrams enormously. Similarly, when asked to produce diagrams from descriptions, participants given functional descriptions drew arrows, but participants given structural descriptions did not.

DESIGNING EFFECTIVE GRAPHIC DISPLAYS

Two General Design Principles

We have come quite naturally to issues of design of effective graphic displays of information. Trade-offs are inevitable but also informative and helpful. For clear communication to ordinary people, reduce the data to essentials; for data exploration by experts, provide more data in many forms. That is, provide the information needed for the task at hand. That is, of course, easier to say than to do as different tasks and different users have different needs.

More generally, good graphics should conform to two principles, one about the content and form of the representation and the other about the perception and comprehension by the user (Tversky et al., 2002; see also, Norman, 2013). *Congruence*: the structure and content of the external representation and should correspond to the desired structure and content of the internal representation; *Apprehension*: the structure and content of the external representation that should be readily and accurately perceived and comprehended.

A case in point is animation. Animated graphics do not stay still; they keep changing. According to Betrancourt and Tversky (2000, p. 5), "computer animation refers to any application which generates a series of frames, so that each frame appears as an alteration of the previous one, and where the sequence of frames is determined either by the designer or the user." Animations can be attractive and pleasurable in and of themselves as attested by billions of viewers of films, videos, and more. In interface design, they are used for that and for many other ends: to attract attention, as our eyes quickly attend to moving things; to keep us oriented as we move in a virtual world or as the world we are viewing moves; to show patterns of movement like the flow of fluids or schools of fish; or to present or explain behavior or processes. An especially informative survey of animation in interfaces (Chevalier, Riche, Plaisant, Chalbi, & Hurter, 2016) reduces 23 uses of animation to 5: keeping context, teaching, improving user experience, data encoding, and visual discourse.

The use of animation to teach, to explain behavior or processes, is of special interest here. Because these animations use change over time to convey change over time, they conform to the Congruence Principle (Tversky et al., 2002). However, a research survey on explanatory animations used in a multitude of contexts revealed that animated graphics did not surpass static ones when the content was equivalent and when interactivity was not allowed (Tversky et al., 2002). It is known that interactivity can have benefits but can also hinder or not be used at all, depending on the kind, content, purpose, and mode of interaction.

What accounts for the failure of so many explanatory animations to surpass their static equivalents? On the one hand, animations often show too much too fast, violating the *Apprehension Principle* (Tversky et al., 2002). But there are other disadvantages of animations. Showing is not explaining, and typically, animations only show. Animations usually show processes in proportional time, but the events underlying animations are naturally segmented into steps by changes in actions and objects, steps that rarely occur at equal time segments (Zacks et al., 2001). Moreover, processes and events that occur over time are usually explained as a sequence of discrete steps. Designing effective animations is complicated and it appears that there has been progress. A more recent meta-analysis (Bierney & Betrancourt, 2016) provides some encouragement for the use of animations in educational settings.

Well-designed animations for other purposes can be effective (Chevalier et al., 2016), for example, animations that are designed to keep viewers interested or animations intended to show patterns of motion, from fluids to fish to football. Especially effective are animations aimed at preserving orientation in space and time as we explore environments or as we observe and track changes in displays of people, things, or data, for example, from bar graphs to correlations (Heer & Robertson, 2007; Heer & Shneiderman, 2012).

How to Find Cognitive Design Principles: The Three P’s

Congruence and apprehension are good principles but do not provide guidelines for specific applications. Good designs often arise from trial and error in communities of users interacting on various tasks. Language is an example; language emerges in large and small communities and changes as needs and goals change (e.g., Clark, 1996; Donald, 1991). So too for commonly used visualizations, like sketch maps. This natural process of iterative trial and error can be shortcut in the laboratory to provide empirical methods to find and test design principles through a program we call the Three P's: Production, Preference, and Performance (Kessell & Tversky, 2011; Tversky et al., 2007).

The application of the Three P's to the design of data visualizations has provided unexpected insights as well as cognitive design principles. In one set of studies, people were asked to produce representations of people in places at different times. People primarily produced tables or line graphs that connected people to places over time. The forms of the representation elicited qualitative and quantitative differences in inferences. There were more inferences and more varied inferences from the tables than from the line graphs. For example, there were more inferences about relations among people from tables. By contrast, the line graphs encouraged inferences about movements of people (or things) across places and time. These are quite frequently the kinds of inferences desired when tracking diseases or drug trafficking (Kessell & Tversky, 2011; Tversky, Gao, Corter, Tanaka, & Nickerson, 2016). The lesson is to choose the form of representation that encourages the desirable inferences—tables for more varied inferences, lines for inferences about movement in time. In another application, people produced, preferred, and performed better when continuous relations were represented by continuous graphics and discrete relations by discrete graphics (Tversky, Corter, Yu, Mason, & Nickerson, 2012). That insight led to the successful design of a touch interface for math: discrete one-to-one gestures for addition and continuous gestures for estimation (Segal, Tversky, & Black, 2014). The general cognitive principle is one of congruence: the form of the representation or the interaction should be congruent with the form of thought.

The Three P's has been successful for the design of info graphics starting from assembly instructions; think of putting together knock-down furniture, as well as the design of data visualizations. For assembly, first one group of participants *produced* instructions after completing assembly. Another group rated *preferences* for those instructions. From this we extracted potential design principles and then tested those for efficacy of *performance* in a third group (Agrawala, Phan, Heiser, Haymaker, Klingner, Hanrahan, & Tversky, 2003; Tversky, Agrawala, Heiser, Lee, Hanrahan, Phan, Stolte, & Daniel, 2007). The cognitive design principles that emerged have broader implications for explanations and stories, including data stories: show step-by-step, show each causal action, show perspective of action, that is, show each step in the process and show how the steps are connected.

LOOKING FORWARD: INSIGHTS FROM COMIX

Like traditional visual explanations and stories, comix present step-by-step boxes so that these are sometimes referred to as comic book explanations. Of course, comix do so much more, as shall be seen. They differ from animations in a critical way: each new frame may not be an alteration of the previous one. In many cases, people do not need the perception of continuous motion. Filmmakers, novelists, and nonfiction authors know this well, and often jump spatially to different perspectives or places, or jump temporally to different times, even prior ones, or both. Their audiences can typically follow these cuts and eventually make sense of them.

Step-by-step presentations predate comics, going back to bread-making in Egyptian tombs, Trajan's column depicting Roman military victories, and the Bayeux Tapestry depicting the events leading up to the Norman conquest of England culminating in the Battle of Hastings. Designing step-by-step presentations requires: appropriate segmentation, appropriate presentation of each segment, and appropriate connections of the segments. Comics and graphic novels have gone far beyond step-by-step presentations. They have developed a stunning range of visual-spatial tropes for telling stories that verge on the poetic, but more accessible than poetry in words. Most of the tropes have no parallels in language and lack Greek names. These examples should provide inspiration for designers of stories relying on data or any kind of visual-spatial story or explanation. There are far more than we can present here. Sadly, indeed ironically, we are limited to descriptions here. Some comix devices have already been adopted in data storytelling (e.g., Bach, Kerracher, Wim, Hall, Carpendale, Kennedy, & Riche, 2016).

Every designer will want to keep McCloud's *Understanding Comics* (1994) close at hand. It is a comic that analyzes comics, and in doing so, provides insights into storytelling and story-understanding in general, and in the conjoint use of depictions and language to do so. Also to be kept close at hand are Spiegelman's *Co-Mix* (2013), a grab-bag of insights from one of the masters of the medium and Eisner's *Comics and Sequential Art*

(2008), more insights from another master of the medium. Studying the oeuvres of both Spiegelman and Eisner and many many other practitioners of the medium will also be rewarding. Larry Gonick's cartoon guides to many disciplines, such as physics, chemistry, genetics, calculus, history, and more, provide a cornucopia of creative and insightful visual storytelling (http://www.larrygonick.com/).

There has been lively discussions of what to call this medium and what it includes. Here we will use Spiegelman's *Co-Mix* (2013) to encompass combinations of words and graphics in comics, graphic novels, graphic journalism, graphic nonfiction, and cartoon textbooks.

Boxes/Frames

Comix have rhythms and are typically segmented by pages, boxes, speech balloons, and speech bars. They are read from top-to-bottom and left-to-right in European languages, but right-to-left in Japanese. Groensteen's fascinating book, *The System of Comics* (2009), analyzes the structures and meanings of the hierarchical and spatial arrangements of boxes, balloons, bars, and the visual means of enclosing and categorizing some information and separating it from other information. Many artists begin with pages devoid of images with 3×3 or 3×4 arrays of boxes, and they fill those in with the story. Others prefer the freedom of using larger and smaller boxes, or no boxes at all. Some introduce a story with a splash page, a two-page spread much like an overture or a trailer, that includes many of the characters and scenes and themes that will follow. Other splash pages simply show the overall setting for the story. A frequent successful device is to overlay that kind of splash page with the typical rows of boxes that show the action of story. This allows readers to get an overview and detail at the same time.

We know the meanings of boxes: they bind and bound. They contain a set of related things and separate that set from other sets of things. Bigger boxes contain more stuff and smaller ones less. In art, rules and restrictions are meant to be artfully broken. The same applies for boxes. In a fanciful comix retelling of *The Three Pigs* (Wiesner, 2001), the first pig breaks the fourth wall. Then he walks into the gutter—the space between the frames—and peeks back into the preceding frame to tell the second pig, "Come on—it's safe out here." This trope acknowledges that the story is in the boxes, and at the same time, entices the reader into the meta-story outside the boxes. In fact, the pigs all come out and proceed to stamp on the wicked story in the boxes to the delight of readers. In another case, a character in one frame, the young physicist Richard Feynman entertaining several women at a party at Columbia, reaches out of his frame back to a character in a previous frame, his girlfriend dancing with a gentleman at MIT, to hand her a letter (Ottaviani, 2011).* Breaking the frame has also been used to defy time in science fiction: imagine a character in a later frame handing a weapon to a character in need in an earlier frame.

Frames have also been used figuratively with double meanings to great effect. In a wordless panel by the early 20th century comics artist Winsor McKay, a sequence of frames shows a child's evolving sneeze; when the sneeze bursts, the frame shatters, to the bemusement of the child. In order to show the extreme speed of a chase, Jim Harriman, the creator of the manic Krazy Kat, depicts the chase in a diagonal sequence of narrow tilted frames sweeping down the page.

Segmenting

Unlike films, comix are highly discontinuous and abbreviated, packed into separate frames or boxes. Boxes contain and separate. They segment time and space. How should that segmentation be accomplished? And what should be depicted in each frame? The research on event segmentation and on the Three P's suggests two cognitive design principles: (1) segment by goals and subgoals and (2) show the most informative parts of the events in each segment, the breakpoints. Indeed, for visual explanations like furniture assembly, this technique seems to work well, and should work well for data storytelling. Many data stories do concern changing events over time and the designers' goals are often to tell the stories in a straightforward way.

By contrast, designers of comix stories often want drama and surprise, which demand not telling stories in a straightforward way. Time can be drawn out by showing small changes in successive frames or chopped up into jumpy, staccato changes. McCloud (1994) discusses some of visual devices that can alter the experience of time.

Connecting: Visual Anaphora

Because successive frames in comix are typically not continuous, comix need to provide ways for readers to bridge the gutter, to understand what is happening from frame-to-frame. Language does that with anaphora.

* I am indebted to Jon Bresman for this and many other examples as well as hours of enlightening discussion on the art and design of comix.

Consider: The boy fled the scene recklessly. He tripped and fell. The "he" refers back to the boy, so the reader knows it's the same person. If the second sentence began with "She," the reader would look back farther to find mention of a girl—or be confused. Similarly, comix often use visual anaphora; some thing or things in frame n carried over to frame $n + 1$ to let the readers understand that we are still on the same sequence of events. If many things change, we have jumped to another place or another time.

Metaphors

Visual metaphors are common in comix, and even more so in cartoons, historically as well as contemporary. Much can be learned from studying them. In a piece for the *Los Angeles Times*, Winsor McCay depicted a businessman walking rapidly on the streets of New York; the street rolls up into a treadmill, and the man keeps up his pace. In his comic strip *Little Nemo*, McCay depicts Little Nemo asleep in bed. Soon he is transported to dreamland. To show that, McCay has the bed's legs grow longer and longer and take Nemo outside into another world. When the dream ends abruptly, as dreams do, the long-legged bed dumps Nemo back into his real one (see Figure 2.6). Visual metaphors provide rich meanings that cannot easily be conveyed in words. They are distinctive and memorable.

Visual Jokes

Humor is always welcome: all the more when it carries deeper meaning. The metaphors described above carry humor: the street rolling up into a rat race, the bed grows long legs that transports Nemo to dreamland. To create the feeling of a mad chase, Krazy Kat racing after a huge rolling stone that is wreaking havoc, Herriman draws the frames diagonally across the page. When McCay's Little Sammy sneezes, the frame shatters (see Figure 2.7). The grandmaster of visual jokes is Saul Steinberg, whose cartoons were far more than jokes. His telescoped maps, oversized close-up and shrunken in the distance visualized our conceptual myopia, what is close looms large, what is in the distance, spatially, temporally, socially, and politically is less consequential. Steinberg shows pompous people in conversation, but the speech bubbles contain a gibberish of symbols: noise without meaning.

Perspective

The view presented to readers can be from varying distances and varying perspectives depending on the intended meaning. Close-ups naturally

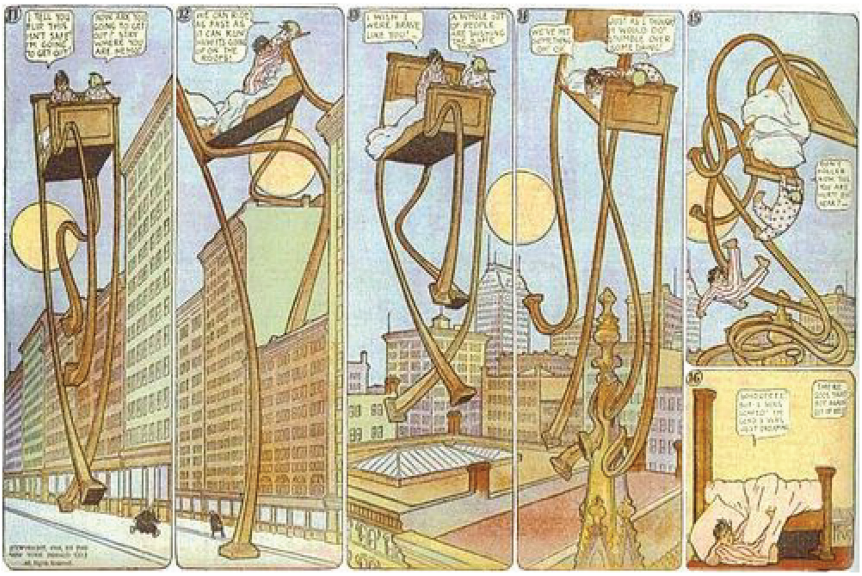


FIGURE 2.6 Little Nemo's dream by Winsor McCay.

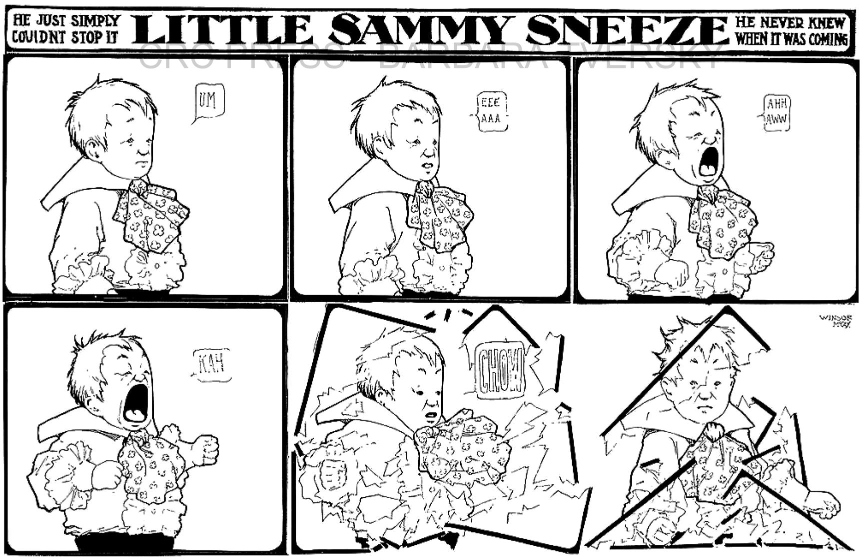


FIGURE 2.7 Little Sammy by Winsor McCay.

give intimacy; at the same time, they ignore context. Graphic presentations can easily switch perspectives within a scene to highlight the perspective of one person or point of view or another. Similarly, graphic presentations can provide overview perspectives that create distance and give broad overviews and more equal weight to everything rather than biasing one point of view over another. Surprising perspectives, for example, from the bottom of a scene, can jar readers and make them see things anew. In visualizing demographic data, turning the world map upside down is dramatic, even confusing, but does lead to recalibration, reinterpretation, and reconsideration by audiences.

Words, Symbols, and Pictures

Picture and words can be complementary, contradictory, redundant, or supplementary. Words and symbols themselves can be depictions. They can look loud or important by being large or thick; they can be sounds or tastes or smells or motion or vibrations. Comix can convey far more sensations than the visual and the aural. Depictions can contrast ironically or poignantly with words. A small child is listening to an adult describing a brutal murder. The adult says X was "rubbed out," a Britishism for murder. The child imagines a picture being erased, as "rubbed out" also means erase in British English (Gaiman & McKean, 1987).

Simultaneous Parallel Stories

Comix can tell two stories simultaneously by breaking up a page into two sets of frames that are easily distinguished, say by color or theme or foreground/background. One powerful page simultaneously can show a murder in depictions and the terrifying sounds rendered into letters. Another can show the present actions of a man in the foreground and his actions in the past in the background.

Double/Triple Meanings

We have seen that boxes and frames both contain and separate, a convenient and elegant double meaning. Our first pig stepped out of the comix world into another one. An example of a triple meaning is created by an old fashioned phone cord. A green female superhero is talking on the phone to three co-conspirators. The phone cord, representing itself, is wrapped around each of the three frames of the co-conspirators. The phone cord thereby represents the frames as well as defining, drawing together, the group of conspirators.

Words

Comix introduce words in several different ways, using visual-spatial means to differentiate them. Speech appears in balloons with tails pointing to the speaker; thoughts also appear in balloons with the thinker indicated by a column of circles in decreasing size. Commentary or narration is typically presented as text in italics either at the top or the bottom of a frame, separated from the frame by a boundary line (see Groensteen, 2009). Talk can be expressed in multiple ways—sentences or isolated words in odd fonts and sizes, grunts, gasps, and other noises. Commentary appears in canonical sentences. These conventions help readers interpret the many levels operative in comix, but like all the conventions, they can be broken for effect.

A Caveat on Culture and Language

Both culture and language appear to affect qualities beyond content of depictions in comix, picture books, and information visualization. The street scenes in Eastern cultures are judged more complex than those in the United States (e.g., Miyamoto, Nisbett, & Masuda, 2006). Correspondingly, covers of popular Korean picture books were judged to be more complex and convey more action than covers of popular U.S. picture books (Won, 2011), and eastern comics were judged to portray more action than western (Tversky & Chou, 2010). Similarly, popular Chinese visualizations of *addition*, *subtraction*, *multiplication* were rated as more complex than U.S. visualizations (Wang, 2011; Zhang, 2014). Designers may need to take these differences into account (Tversky & Chow, 2017).

RETURNING TO DATA

We have not forgotten those stripped-down points anchored in various information spaces. Fundamental questions for a data journalist crafting a story are: what data are relevant? How should they be displayed? Data can be quantitative, those stripped-down points, or qualitative, beginning with eyewitness accounts (n.b., these are often not reliable). Spatial/structural data lend themselves to descriptions, data such as patterns of disease, crime, housing prices, or organizations of governments and corporations. Temporal/causal data lend themselves to explanations and stories, the actions of individuals, changes in gross national product (GNP), population, or education over time. Spatial/structural data invite maps and organizational charts; temporal/causal data invite flowcharts and line graphs. Many creative designers have developed beautiful graphics that are tempting to use, but if everyone adopts the same displays, they will be confused in memory. Yet another trade-off. One goal of data storytellers is to make their stories distinctive, individual, and memorable. Another goal is to insure that the displays encourage the desired (and true) inferences and conclusions intended by designers.

DESIGN OF THE WORLD: *SPRACTION*

From the design of graphics to the design of the world, to *spraction* (Tversky, 2011). So little of the world is wild. Our actions design the world, the space around us: into rows and columns on shelves and buildings and streets that reflect categories and hierarchies and orders; into rooms and buildings with themes; into table settings and buildings with 1-1 correspondences and repetitions and symmetries. The actions that create the organizations, putting, ordering, lifting, turning, separating, and more, get abbreviated into gestures that communicate those actions, literally or metaphorically. Those words are used to describe our thinking, our mental actions on thoughts. The patterns created by the conceptual organizations form templates for graphs and charts: bar charts, matrices, and line graphs. These ways of organizing the world represent highly abstract concepts. The patterns created are good Gestalts that attract the eye and invite reflection: what do they mean? Spraction: actions in space express abstractions.

PULLING THINGS TOGETHER

We began with the observation that stories have universal appeal, that they are like life, but better. We have taken a tour of the many layers that contribute to storytelling, to visual-storytelling, and to visual data storytelling including understanding events, retelling events, creating visual-spatial meanings, and discovering cognitive design principles for effective graphics. Communication first developed face-to-face, and communication in the wild uses many layers and modes simultaneously—words, prosody, gestures, actions, and props in the world. The freezing of communication into depictions in caves, on stone, in stained glass windows, and words on tablets and paper allowed preserving and disseminating knowledge, but it also led to separating the natural layers and modes and even eliminating some of them, notably prosody and gesture. Contemporary visual explanations, data journalism, and comix reunite depictions, graphics, and language and even prosody and gesture in rich and varied visual forms; they expand the form and enlarge our understanding with a wealth of delightful visual tropes.

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