Design Patterns for Data Comics

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ABSTRACT
Data comics for data-driven storytelling are inspired by the visual language of comics and aim to communicate insights in data through visualizations. While comics are widely known, few examples of data comics exist and there has not been any structured analysis nor guidance for their creation. We introduce data-comic design-patterns, each describing a set of panels with a specific narrative purpose, that allow for rapid storyboarding of data comics while showcasing their expressive potential. Our patterns are derived from i) analyzing common patterns in infographics, datavideos, and existing data comics, ii) our experiences creating data comics for different scenarios. Our patterns demonstrate how data comics allow an author to combine the best of both worlds: spatial layout and overview from infographics as well as linearity and narration from videos and presentations.

ACM Classification Keywords
H.5.2 User Interfaces: Theory and methods

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Visualization, Comics, Story-telling

INTRODUCTION
Communicating with data or 'data-driven storytelling' is capturing the attention of the visualization research community [40, 38]. Crafting visualizations that effectively communicate insights on data while keeping the audience engaged relies on many factors: the characteristics of data, the communication medium, the narrative and the audience, as well as the purpose of the communication. There are different common *genres* of data-driven storytelling such as magazine style articles (text+figures), infographics, videos, presentations, as well as comics [48]. Each genre affords different opportunities and limitations for communication (e.g. leveraging text as well as pictures, enforcing linear structure, providing a high-graphical resolution, supporting reader interactions).

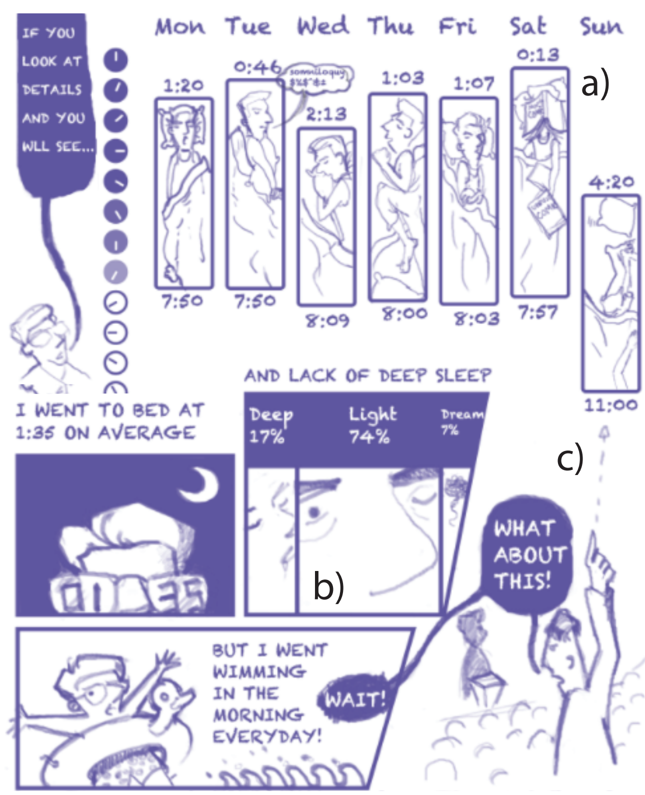

Figure 1. Data comic example employing design patterns: a) *temporal sequence*, b) *bar-chart panel*, and c) *flashback*. (©Zezhong Wang)

This article focuses on *data comics* [57, 10], a format inspired by the visual language of comics and the way people read and understand graphic narratives. Comics can be broadly described as *sequential art* [20] and *juxtaposed images and words* [41]: they map time into space through the use of panels and their ordering. Comics are not yet a common genre of data-driven storytelling. However, we believe they are promising as they combine assets from two common practices: they provide

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the freedom of 2D spatial layout present in infographics and annotated charts, while supporting the linearity of narration naturally enforced by videos and live presentations. Arranging panels in space enables the reader to gain an overview of the narrative and its structure (page) while keeping the details of each of its points (panel content) accessible at any time, allowing the reader to consume the story at their own pace. Arranging panels in a sequence guides a reader's attention and helps to build a narrative, with a beginning, middle and end, tension, argument, immersion, and emotion. By filling the space between those two worlds [27], comics allow an author to combine the best of both worlds in a single format.

This combination opens up a large potential for expressive storytelling with data visualizations. While few examples [44, 12] of data comics exist, there are no guidelines, methodologies or tools that help crafting them. To facilitate the creation of data comics and to inform the design of interactive and eventually semi-automated design tools, this paper proposes a set of design patterns for data comics. A pattern describes a *a set of panels with specific layout and content relation*. Thus, a pattern describes both usages of space and a relation between the content inside the panels. For example, the data comic in Figure 1 uses the *flashback* pattern (c) by introducing a reference between two non-consecutive panels. Other patterns include *temporal-sequence* to depict temporal change (a), often simplified into small multiples [7]. Such design patterns provide an extensible set of templates that can help in the creation phase of comics as well as being used to teach data comics in classes and workshops.

We composed and refined our set of design patterns by following three complementary methods. First, the authors of this paper—an interdisciplinary team involving a comic artist, an art graduate, as well as researchers in visualization— created over ten data comics for different data and audience (Section 3). By crafting and iterating over these comics, we reflected on an initial set of design patterns that we found useful in the creation process and that reoccurred across the comics we generated. Second, we identified a design space to systematically describe our patterns leading to the description of new patterns (Section 4). The design space is informed by i) coding spatial layouts common in the space-oriented genres of infographics and traditional comics, combined with ii) linear narrative progression between panels (frames) in the time-oriented genres, building from Hullman et al. [33]. Third, to assess the value of our design patterns for teaching and creation of data comics, we ran a workshop with 23 participants creating data comics for multiple datasets (Section 5). We printed a set of design patterns cards akin to IDEO [3] and provided them to the workshop participants. Participants leveraged these cards to create a set of comics from data we provided them. Subjective feedback from the workshop suggests that the cards were useful in the ideation and execution process. All material in this paper including examples of existing data comics, comics that inspired our patterns, our own data comics, design cards, as well as the entire material of the workshop, can be found online: http://datacomics.net.

BACKGROUND

Genres in Data-Driven Storytelling

The term *genre* has been coined by Segel and Heer [48] to describe seven types of narrative visualizations: magazine style, annotated chart, infographic, video, slide-show, flowchart, positioned poster, and eventually comics. For the purpose of this work, we classify some of them as *space-oriented* (infographics, posters, annotated charts) and others as *time-oriented* (videos, slide-shows). Space-oriented genres present and communicate through space: layout, size, visual and graphical elements organized on a canvas, equally and instantaneously accessible to the reader, leaving it to the reader which elements to watch, how long, and in which order. The time-oriented genres present and communicate linearly over time; they have an order with a fixed beginning, a middle, and an end; a development over time, an argumentation and they can present change over time through animations [6]. Observers are locked in the order and pace in which they perceive the content. Research has shown that narrative structure is intrinsically easier to remember and facilitate readers engagement and persuasion [25]. However, this requires the audience to remember, to continuously pay attention, and to adapt to the pace chosen by the presenter. In short, while animated explanations can be useful to present dynamic content [31], animations often risk to show "*too much, too fast*" [54].

A third group of genres can be described as both spatial *and* temporal. This includes magazine-style (text with figures) as well as comics. Comic scholar Groensteen writes that *"[c]omics is not only the art of fragments, of scattering, of distribution; it is also an art of conjunction, of linking together.* [26, p.22]. Comics combine linear narration with non-linear figures and, as Eisner notes, the *"partnership of words with imagery become the local permutation. The resulting configuration is called comics and it fills a gap between print and film."* [20, p.xvii].

Comics for Data-Oriented Storytelling

Comics have been used in facilitating classroom education [32, 52, 50], conveying scientific phenomena [53, 22], and to storyboard interaction design [19]. These first examples demonstrate the potential of comics to present scientific information in a clear and accessible way. The comic page layout allows a reader to consider information on multiple levels: a detailed explanation in sequence, as well as browsing the concepts and explanations simultaneously [51]. A single panel acquires meaning from its individual content as well as from its position within the global visual/narrative structure—a process defined as "braiding" (*tressage*) [27]. Comics can use transitions [41], simultaneously providing detail and overview (*co-presence* and *configuration*) [28], thereby preserving visual permanence [56] and allowing readers to read the story at their own pace. Besides their linear structure, comics have a rich history of integrating unexpected logics into their structure, such as hierarchical linguistic grammars [17], repetition [49], or musical elements that carry temporality, emotion and a joyous disregard for staying in their expected place [15].

Data comics support data-driven storytelling by making use of peoples' familiarity in reading and understanding comics along with the particular qualities of the medium [57, 10]. There is not a precise definition of what is or is not a data comic, rather data comics combine elements from different genres, presented in a unique visual and narrative framework. Bach et al. [10] describe four essential components that help discussing the uniqueness of data comics: the presence of *data visualization*; *flow*, whether linear or non-linear; *narration* to include and illustrate contextual information and create a compelling narrative as opposed to a factual presentation of charts; and *words-and-pictures* combined visually using multiple strategies. The patterns presented in this work are most close to the dimensions of *flow* and *narration*.

While we can find many examples of data stories that include some elements of comics (juxtaposition, combination of text and image, etc), very few examples exist that combine these components into a fully fledged data comic. Nature provides a high quality example on the challenges of climate change [44] in 2015 combining data visualization, narration, linear-and-non linear flow, into a compelling, visually striking and even emotional piece. Cisneros created an interactive comic using Tableau Graphics [16]. Additional examples include a scientific report on the change of water temperatures [12] and graph comics [8]. Part of this may be due to a lack of tool support; besides Zhao's and Elmqvist's editor prototype [57] that allows designers to embellish data visualizations with comic elements, data comics authors have to craft their comics manually, which generally entails laboriously switching between data visualization tools and illustration tools [13].

Design Patterns in Education and Design

Packs of cards containing design patterns are a common resource for creative practice, supporting creation and analysis in both classroom and professional situations [3, 2, 1, 21]. For visualization, a wealth of online collections of visualization design patterns exist (e.g., [46, 47]), but without a systematic scientific foundation. *VizItCards* is a card set figuring visualization types and tasks in visualization [29], specifically designed for education.

For storytelling, Segel and Heer have described general design strategies [48], including *details-on-demand*, *multi-messaging*, *progress bar*, and *time-slider*. These strategies are similar to our design patterns but do not describe the specific design space of (static) data comics. For data-driven storytelling, Bach et al. [11] describe general higher level narrative patterns for data-driven storytelling (e.g., *addressing-the-audience*, *exploration*, or *gradual reveal*), some of which were described as patterns that define the "flow" of a story: *exploration, gradual reveal, repetition, speed-up/slow-down*. While none of these mentioned patterns are specific about the storytelling genre, the actual implementation of pattern depends on the genre and its media. Some of these patterns can be translated into narrative comic design patterns, as shown later.

DATA COMICS USE CASES

To obtain more examples of data comics and to explore design patterns, we created 11 data comics aiming for a diverse set of datasets and audiences. Creating one comic, including gathering data, storyboarding, iterating, and finalizing took between one and three days. The complete list of examples can be found online.[1] In this section, we briefly describe three examples (Figure 2) to introduce a few design patterns we found in these comics (highlighted in black in the following).

Wannacry

The comic in Figure 2-left illustrates the outbreak of the Wannacry virus in 2017. It is held in dark colors, contains lots of illustrations, and few actual data visualization. The first four panels create an **exposé**, introducing the virus and how it works. The panels in row three show a **time-sequence**, one panel per day showing the number of infected computers. The last panel shows the **larger picture** of all the organizations infected on the 5th day. Several individual panels **annotate** some selected companies by showing their logo. This comic was intended for general information, e.g. on social networks.

O'Keefe's Experiment

Figure 2-center shows a comic explaining one of the neuroscience experiments which lead to the discovery of place cells and the associated maps, for which John O'Keefe was awarded the 2014 Nobel prize in Medicine and Physiology [45]. While several explanatory videos were created after the Nobel prize announcement[2], the linear structure of time-based media limits the communication of the complex process. We feel that data comics afford more freedom here: a **larger panel** was used to place the aerial view of the rat maze (adapted from Fig.2 of the original paper) in relationship to the real-life experimental setup. Repeating this aerial view creates a **time-sequence** showing the animal moving through the maze, in parallel to the brain recordings coming from the experimental rig. This juxtaposition simulates the point of view of the experimenter, making explicit the relationship between the animal position within the maze and the brain activity. Finally, the sequence **builds up** to a more conventional representation of a 'place cell' map (adapted from Fig. 2 of the original paper).

Through combination and nesting of basic data-comic design-patterns we were able to visualize all the steps required to go from an experimental setup to high level experimental results. However, contrary to the frames of a video, the comic panels allowed us to preserve the logic connections and visualize them simultaneously on the page, so that at any point and in a single gaze the reader can be reminded of the larger picture, and move within the explanation at will.

USAid Data Reports

A third comic illustrates the development strategy of USAid in Uganda. Local teams gather data which is compiled into charts and maps and then explained in data reports [5] that support decisions about future strategies. However, these reports are too dense and text heavy to communicate the goals of USAid to the general public.

Our data comic is designed in collaboration with USAid for use on their website. Together, we defined audience, presentation medium and settled on explaining the situation of a

[1] http://comics.datacomics.net

[2] E.g. https://www.youtube.com/watch?v=GmFspbHHZ_w

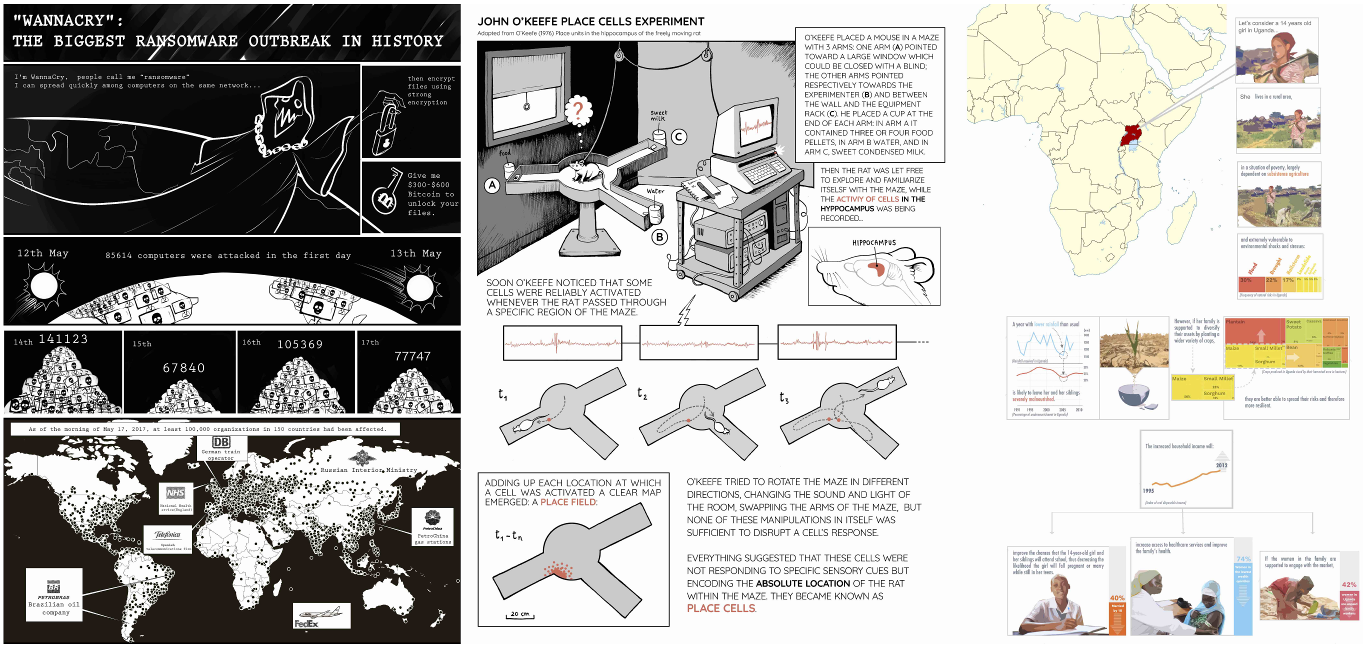


Figure 2. Three examples of our data comics. Wannacry outbreak (left) (©Zezhong Wang); O'Keefe's experiment (center) (©Matteo Farinella); US development aid in Uganda (right) (©Zezhong Wang).

14-year-old Ugandan girl, the focus of the current USAid development strategies. The comic (Figure 2-right) starts with a **larger panel**, locating Uganda. It then links a set of three **exposé** panels, introducing the central figure of the comic. The exposé ends with a **panel-barchart** showing the share of natural disasters the girl is confronted with. Then, the comic contrasts two charts and shows an **annotated transition** (arrows that grow the small yellow rectangle into a larger colored treemap). Eventually, the linear sequence gets broken, leading to three **facets** (the last three panels). The full comic with the remainder can be seen online.

To conclude, these comics as well as the other 8 ones led to a number of data-comic design-patterns (highlighted in bold face) that we identified. The next section details a design space to systematically describe these patterns and to generate more patterns.

PATTERN DESIGN SPACE

The goal of our research is to facilitate the creation of comics from data. We set out to identify patterns that capture the way data comics can present information and create narration. We coded patterns from 9 existing data comics[3] plus our own 11 comics mentioned in Section *Data Comic Use Cases*. From these examples, we could describe an initial set of 29 design patterns which informed our design space. The design space then provided 1) a structured terminology, and 2) a frame of thought to systematically brainstorming new patterns. This allowed us to describe 13 more patterns, not captured by any comic so far. Dimensions of the design spase were not defined *a priori*; we followed an iterative process with 3 individual authors creating and refining their own patterns and categories. The final categories were decided by consensus (>12 hour long discussions) and final review.

[3] http://comics.datacomics.net

As data comics combine spatial presentation with narration, **we define a data-comic design-pattern as** *a set of panels with specific layout and content relation*. A design pattern hence presents a specific solution to a narrative purpose, by proposing a graphical layout and the content of the individual panels. Consequently, our design space combines a dimension for *spatial panel-layouts* with a dimension for *content relation* between panels. A design pattern can be described by a combination of both dimensions. However, some combinations can describe multiple patterns and their variations.

Some patterns are commonly used in infographics as both genres use the visual space for graphical expression. For example, many infographics use a layout grid and group elements hierarchically; some show small multiples to convey changes over time or show different facts of the data; some infographics are designed to guide the reader's view in a specific way by playing with size, color, and layout. While the visual distinction between infographics and comics is sometimes blurred, we articulate three main characteristics of the data comics genre as compared to other genres: the notion of panels, a narrative relation between panels, and a guided layout.

Panels

The central narrative device in a comic is the *panel*, defined as a frame "*depicting a frozen moment*" [4] and the camera through which the reader perceives the "world" [42]. For the sake of our research, **we define a panel as** *a narrative element that captures a moment in the narration and focuses the reader's attention*.

While panels are inherent to comics it helps to extend their notion to the other narrative genres such as infographics, posters, slideshows, and videos (Figure 3). In infographics and posters (the space-oriented genres), a panel corresponds be any graphical component that can be understood as a narrative element

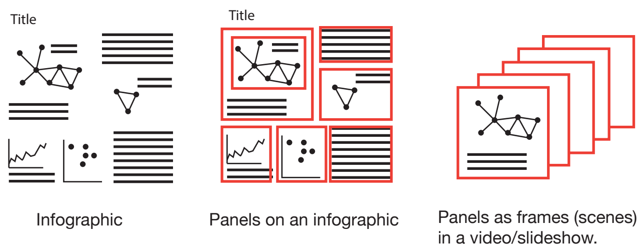


Figure 3. Extending the notion of a comic panel (red) to infographics (left, center) and videos (right).

and that is somehow separated from the rest of the visual space (e.g. through a border or empty space). In infographics and posters, a panel can be a paragraph of text, a single image, or any combination of both. Sometimes, panels are made explicit by a drawn frame; sometimes, panels are separated from each other through white space (or even pages) and can be nested.

In videos and presentations (the time-oriented genres), a panel corresponds to a single frame or a short scene, including spoken or written word. Panels in videos and presentation are separated from each other through time. While panels in infographics are juxtaposed in space, panels in videos are sequenced into a unique temporal order. Transitions between panels can be abrupt (cut) or gradual using blurring techniques, or animated transitions [30, 9].

Dimension I: Content Relation

A meaningful order and relation between a set of panels in comics can help creating a narrative [28]. A narrative can be linear, e.g., an explanation that spans over multiple panels, a sequence of question-and-answer, a temporal change, an exposé that contextualizes a dataset [11]. A narrative can further be non-linear [23, 36] or entirely open, inviting the reader to explore on their own, possibly after a guided introduction (martini-glass structure [48]). Our dimension of *content relation* describes how the panel content relates.

Relations between just two panels have been described as transitions by McCloud [41] for traditional comics and include time steps (*moment-to-moment*), actions (*action-to-action*), characters or objects (*subject-to-subject*), places or scenes (*scene-to-scene*), aspects (aspect-to-aspect), or no specific relation at all (*non-sequitur*). Similar transitions have been described for data comics [10] and which reflect the more general taxonomy by Hullman et al. [33] on sequences in narrative visualizations: temporal, spatial, granular, comparison, causal, dialog. These transitions and categories have been inspirational to our dimension of *content relation* with some categories maintained: temporal, granular, facets.

Dimension II: Panel Layout

Panels organized on a 2D canvas (paper, screen, slide, etc..), result in a *layout*. For both infographics and comics, many layout types and templates have been described in the literature and on the web [41] but no overview exists that describes layouts for comics and more layouts for such as in infographics within the same space. Moreover, traditional comics provide an extreme richness of examples for non-linear layouts [43], including work by Chris Ware, Richard McGuire, Nick Sousanis [51], Abu Al Rabin, Harvey Kurzman and others.[4]

To identify common existing layouts, three of the authors independently coded a set of 59 infographics from *The Best American Infographics 2015* [18]. In addition, we collected examples of common comics from the comic authors above. By coding layouts we were interested in how these layouts prescribe a specific (guided or open) reading order and how much they make use of spatial relationships between the panels. After discussion, we agreed on the 9 types layouts described below. For our purposes we place layouts in an approximate spectrum between *open/non-linear* and *linear* with guided layout forms in between (Figure 4).

- A **large panel** can convey a lot of details for a single and complex visualization, e.g. networks, large tables, timelines, maps. Reading focus and reading sequence are open.
- **Annotated** are smaller panels related to parts in a larger panel. Smaller panels can be related to positions in the panel through arrows, numbers, or lines. The set of panels creates multiple narrative points and can focus a reader's attention for some narration. This layout has been found mainly in conjunction with maps where smaller panels show details of the map or contain text.
- **Tiled** describe a set of panels, some of them larger, some smaller. There is no specific hierarchy or reading order associated with the panels other than the natural reading order (e.g. right-left, top-down). Large panels might signify importance or simply account for more content.
- **Grouped** creates a hierarchical grouping of nested panels.
- **Grid** shows a set of equally-sized panels in a regular grid-layout similar to a table. In many cases panels contain a similar visualization such as in small multiples. Similar to *Network*, a grid creates multiple possible reading orders, e.g. row-wise, column-wise, spiraling, arbitrary, or column-wise or zig-zag (e.g. left-right/top-down).
- **Parallel** shows two (or more) panels in parallel, vertically or horizontally while leaving the reading order to the reader: each one individually, or switching back between both. Parallels is often used in conjunction with *branched* to show, e.g. alternatives.
- **Network** connects a set of panels in a non-linear way and can create multiple parallel reading orders among a set of panels. Arrows guide a readers attention and make narrative relationships between panels clear.
- **Branched** connects panels similar to a network but keeps a generally sequentially flow: a single sequence branches into alternative sequences which eventually may come together again.
- **Linear** aligns panels in a linear sequence with a single explicitly expected reading order. Reading order can be expressed through adjacency or arrows and is the default layout pattern in most traditional comics. The *linear* corresponds one-to-one to the temporal layout of frames in videos and slide shows. A sequence can be laid out horizontally, vertically, zig-zag, or following an arbitrary curve [14].

[4] http://traditionalcomics.datacomics.net

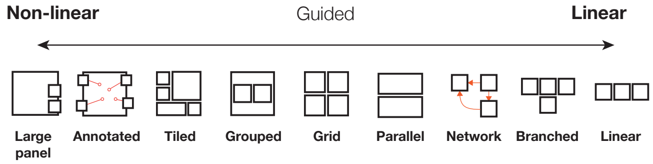


Figure 4. Panel layouts found in infographics, loosely ordered by their degree of linearity. Red elements are flow-marks, indicating reading direction.

Some of these layouts work by an implicit agreed reading order, e.g. top-down and left-right, or adjacency. Other layouts, such as networks, or tiles, may need additional *flow marks*. We define flow marks as all graphical elements that communicate an explicit reading order between panels: arrows, numbers, human characters pointing, etc.

Combining these layouts with a specific panel content, we obtain the design space shown in Figure 5. The next section gives examples of design patterns and relates them back to our comics.

DATA COMIC DESIGN PATTERNS

A design pattern fills one cell in the design space in Figure 5. A pattern is further defined by a name, a description, an abstract illustration as well as examples. The sets of patterns we could find during our research (analyzing comics, drawing comics, workshop) filled about 37% of all cells in our design space (patterns marked with a star). The following systematic analysis of the empty cells filled those combinations which we thought would yield purposeful patterns that we can describe, but for which we did not have an explicit example for. This filled our space to 53%. Thus, patterns for the empty cells might be possible but we did not find any particular purpose for them yet (e.g. *narrative*×*large panel*). Instead, we wanted to keep our initial set of patterns to a reasonable and usable amount and leave it to future exploration to describe more patterns. We intended our patterns to be suitable for a set of workshop design resource cards in the vein of IDEO [3].

In the following, we explain a few representative pattern examples (Figure 6), grouped by their content relation (rows, top-down). The full set of patterns including their name, description, illustration, and examples can be found online.[5]

■ **Narrative Patterns**—Narrative patterns create connections between the data visualizations and the reader, the narrator, and the context of the data. They are powerful devices to build a narration and to address the reader. For example, the **exposé** pattern introduces the data context, problems and questions, demonstrating importance. A **question&answer** can be used to address the reader and involve them into the story. **Multiple explanations** explains and highlights different aspects of the data across several patterns, keeping the visualization the same to avoid overloading a single large picture.

■ **Temporal Patterns**—Temporal patterns communicate a temporal change in the data. **Time-sequences** show a data set over time, using multiple panels to show specific moments or time periods (sometimes called *small multiples* [7]). **Time-grids** arrange a temporal sequence in a grid, implying vertical as well as horizontal reading order; e.g. horizontal panels might be a day apart, while the temporal difference between any two vertical panels is one week (calendar). **Time-nesting** visualizes time hierarchically by nesting panels of shorter events into a panes summarizing longer periods (e.g. important events in each century).

■ **Faceting Patterns**—Faceting patterns deliver complementary views on different parts of the data (similar to *comparison* in [33]). In a **multiple facets** pattern, panels are loosely assembled into a tiled layout or a grid layout. Panels are narratively connected by explanation and the delivering of facts. Content of two panels can be placed in **contrast** by isolating two panels and place them into a parallel layout. **Alternatives** are shown as sequences, branching out of a linear sequence.

■ **Visual Encoding Patterns**—Visual encoding patterns describe explanations that help the reader to understand the presented visualization. A **build-up** can explain the structure of a visualization through a sequence of panels, by gradually introducing the parts; e.g. introducing axes, scales, as well as visual marks and visual mappings. Similarly, a **legend** can be shown in a single panel *prior* to showing the visualization in order to make sure the reader is at least aware of the visual encoding.

■ **Granular Patterns**—Granular patterns relate panels with different levels of detail. The most prominent example is a **zoom**, which can be expressed by a sequence of panels that guide the readers. Alternative patterns are a **cut-out** or a **lens**. A little more high-level are **overview+detail** and **the-larger-picture**. Both involve a large panel, in combination with a sequence of smaller ones. In the first case, the large panel shows the overview for a complex visualization. The following panels then explain details which all relate to the issue shown in the first panel. *The-larger-picture* is the inverse in that a larger detailed panel finalizes a series of smaller panels and can close a story with a general overview, potentially inviting the reader to further exploration.

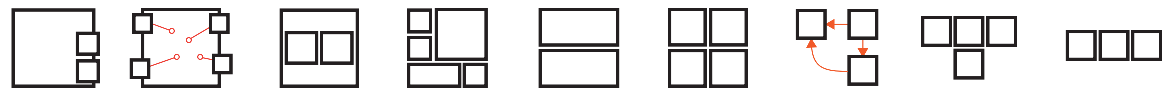
■ **Spatial Patterns**—Spatial patterns create a narration through the same visualization picture. A **space-walkthrough** consists of a single large picture in the background, while overlaying panels in a sequence at the important parts of the larger image. For example, a map showing the route of a travel while each station of the journey features its own panel. Panels may be related through the flow-mark of the journey path.

We also found a set of single panel patterns. These patterns are not specific to comics, but merit being included as we found them both purposeful and useful for teaching: **highlighting** a single or a set of elements in a panel, or **text-legends** that color words in the text if they relate to elements in the visualization.

WORKSHOP

We ran a workshop to investigate: *G1)* the perceived usefulness of data comics; *G2)* whether our patterns help novices to create data comics; *G3)* how difficult it was for novices to adapt design patterns to their own stories; and *G4)* whether we could find novel design patterns.

[5] http://patterns.datacomics.net



LAYOUT / CONTENT RELATION	Large panel	Annotated	Grouped	Tiled	Parallel	Grid	Network	Branching	Linear
Narrative		State panels ★		Multiple-explanations ★		State panels ★	Flashback ★		Exposé ★ Multiple explanations Question & answer ★
Temporal		Time-overlay	Time-nesting	Moments	Before/After ★	Time-grid	Time-States	Alternative tracks	Time-Sequence ★ Overview+detail ★
Faceting				Multiple facets ★	Contrast ★ Alternatives ★	Multiple facets ★		Alternatives ★	Overview+detail ★ Gradual Reveal
Visual Encoding	Legend ★								Build-up ★ Legend ★ Annotated transition ★
Granular	Overview+detail ★ The larger picture ★	Cut-out Lens							Zoom Cut-out
Spatial		Space-annotations ★		Tiled-polyptych ★	Parallel-polyptych ★	Grid-polyptych ★	Space-walkthrough ★		Pan

Figure 5. Design space for data-comic design-patterns: panel *layout* (horizontally) and *content relation* (vertically). Darker cells indicate more patterns. Some patterns occupy several cells as they can be expressed with different layouts. The full list of patterns with names and examples in found online. (*see supplementary material*). Red stars mark patterns we have found or created examples for. No stars mark patterns generated systematically from the design space.

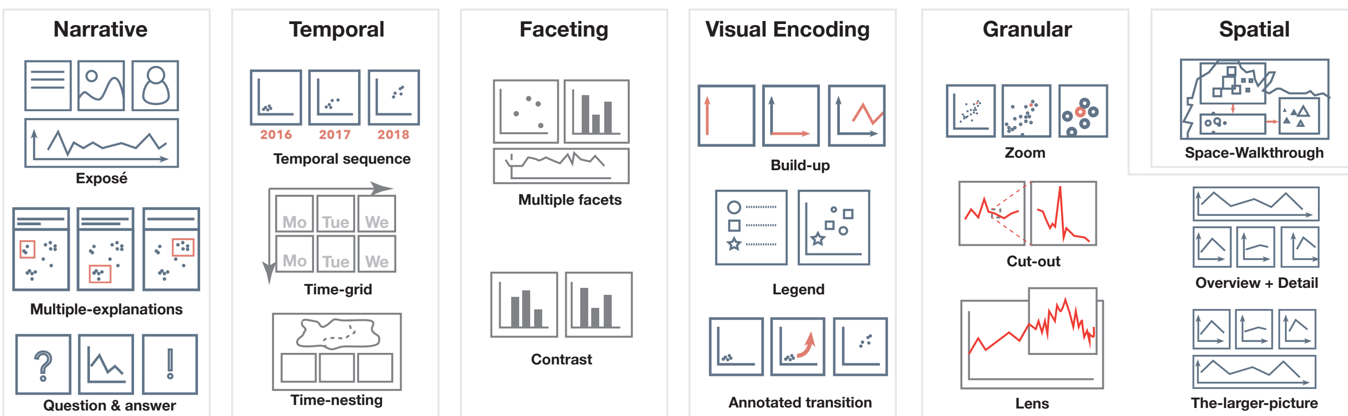
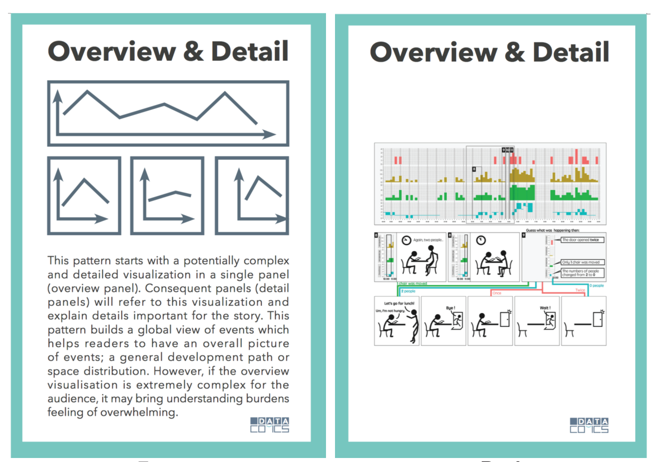


Figure 6. Illustrations for some example design patterns in data comics, organized according their content relation. Stars mark patterns that we identified through making comics (Section "Data Comics Use Cases").

The workshop asked participants to create one or more data comic storyboards—with an emphasis on sketching rather than final polished versions. Participants were given physical design-pattern cards, each showing a pattern name, a brief description of the pattern, an abstract illustration, as well as an example data comic on the backside (Figure 7).



Front Back

Figure 7. Example of a design pattern card for workshop, printed on A6 format: front (left) and back (right).

Participants

The workshop was tailored for students from a range of backgrounds including Art, Design, Data and Computer Science. No specific skills were required and the workshop was announced on the local university's mailing lists. For our 3.5h workshop, participants worked in pairs to support rapid working and iteration.

23 participants (aged between 22 and 29) signed up for the workshop which was not part of any curriculum. Demographically, we had 10 males, 17 Chinese, 1 Indian, 1 South-American and 4 Europeans, all of whom had been living in a western country for some time. 17 participants were graduate students in a program teaching computer science and design skills, three were computer science PhD students, one was a landscape architect and two worked for a start-up company.

Half of the participants indicated an elevated experience with data visualization. Only one participant had drawn comics as an adult, but half of them had drawn comics as a child. They were all unfamiliar with data comics.

Data

Groups were provided with a collection of different data sets and stories, either as infographics, text-only, data videos or raw data. Rather than providing only raw data, we decided to provide around 7 visualizations per topic in order to save time and keep the focus of the workshop on storytelling. Visualizations had been collected from websites and are available in the supplementary material. Participants then decided themselves on a data set, either by browsing the visualizations in our Github-wiki (global migration, CO2 emissions, global health) or searching visualizations on their own initiative. They then either adapted or created a storyline, and were free to re-use any visual or textual elements alongside their own work.

Procedure

The workshop was carried out over three hours on a weekend, without compensation for participants. A 30-min introduction explained the need for storytelling as well as data visualization. The introduction showed examples of data comics as well as traditional comics and introduced the key ideas of panels, page layout, narration and stories (e.g., beginning, climax, end). After the introduction, participants carried out four warm-up exercises: *1)* 10-second individual drawings of a bird, a human, another human, and a bouncing ball; *2)* dividing a sheet of paper into 7 rectangular areas representing panels (20 seconds), *3)* numerating the rectangles in their "natural" reading order, *4)* drawing a short personal story within the seven panels (5 minutes). These short exercises served to practically familiarize participants with the theoretic concepts explained earlier and lower the bar to active sketching.

Groups were formed on a voluntary basis. Each group was given our deck of 23 design-pattern cards along with instructions on how to use the cards (brain-storming, adaptation, combination). Participants could freely browse and discuss the cards in their groups (Figure 8-left). The entire active procedure lasted for 2.5h. Participants could draw on large poster-size paper sheets and/or use post-its to sort their ideas, and create and arrange panels (Figure 8-right). At the end of the workshop, comics were taped to the walls and participants had the opportunity to read through other comics. Eventually, we asked each group to briefly tell their story orally using their comic. This last activity was meant as an exercise of active storytelling, rather than passive storytelling through the comics themselves.

Results

During the workshop, we obtained 11 comics, one per group. Comics varied between 4-14 panels, most using around 9 panels (Figure 9). Right after the workshop, each participant filled in a brief online questionnaire, giving general feedback on the workshop, the usefulness of data comics, as well as the design patterns. Below we report on our main findings.

G1: Data Comics Usefulness: Asked for the potential of data comics to communicate information participants gave an

Figure 8. Data-Comics workshop: (left) designing with pattern cards, (right) storyboarding with post-its.

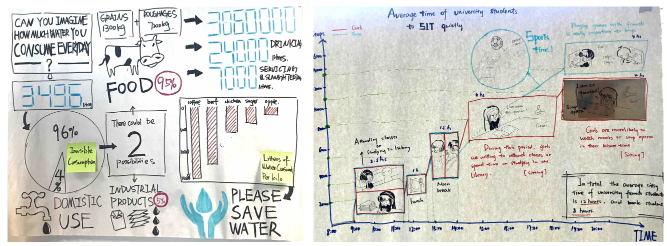


Figure 9. Data-Comic from the workshop: (left) annual water consumption (©Xudong Jiang, Yi He), (right) how long students sit (©Yuchen Ye, Wenqi Cai).

average rating of 5.6 on a 7-step Likert scale 1 7. Participants highlighted their attractiveness and simplicity (*"Easy reading, attracting readers, Interesting"*, *"interesting way to show complicated data"*), and the ability for storytelling (*"It can clearly show (sic) the interpretation behind the data, compared to [a] single static diagram, and it is easier to set up than dynamic diagrams."*). One participant noted *"It takes infographics to the next level, making them useful as a way to journal complicated statistics in an approachable format"*. On the downside, participants mentioned different cultural reading orders, as well as that comics, need more space than text (and figures). One way to prevent reading-order confusion is to use explicit flow-marks.

G2: Pattern usage: We again coded all the comics independently, describing the patterns used in the comics. We found the following patterns and their frequencies: *comparison* (5), *question&answer* (4), *legend* (3), *exposé* (3), *flashback* (2), *multiple facets* (2), *overview&detail* (2), *state-panel* (1), *walk-through* (1), *the-larger-picture* (1) *contrast* (1) and *zoom* (1). Most comics (9/11) used some linear layout, 4 of which strictly relied on linear layout. Given the relative brevity of comics (created in only 2h), the number of patterns found suggests that participants incorporated the design patterns from the cards into their comics. Only one comic did not include any sequential reading and all comics included several panels, rather than a single (detailed) visualization. Six comics featured a linear reading order. Beginnings mostly consisted of questions, while most stories ended with a summary statement. While at first sight, some creations looked like infographics, most contained a clear structure and a driving narrative, making the results different from most presentation-oriented infographics.

G3: Pattern usability: Usability and usefulness of design patterns were overally rated very positive, with an average rating of 7.8, (mode=9) on a 10-scale Likert scale 1 10

. *Understandability* was rated similar 1  10, with an average of 7.6 (mode=9). Mapping patterns to stories was considered considered less simple but very much possible with an average rating of 6.8 1  10. One participant commented that patterns *"were layed (sic!) out very clearly and it made the patterns more obvious"*. Problems encountered were that *"sometimes its really hard to find a really suitable pattern for the specific story"* and a worry that patterns could *"limit the thinking and ideas to some extent"*.

G4: Pattern discovery: We did not discover any new patterns from the comics. While disappointing, this is not surprising given the short timescale and relative novelty. It is reasonable to assume that in a new kind of activity, the participants relied mostly on the patterns we had given them.

Other findings: 8 out of 11 groups used data provided by us and we found that almost all of these (7) invented their own visual representation, rather than sticking to the visualization given in the wiki or found online. Generally, participants simplified visualizations, delivering a single message per panel rather than a single complex graphic. Participants enjoyed the warm-up, and several mentioned wanting more introduction and guidance in drawing. This implies that giving a guided introduction to essential skills (quick sketching, dividing page, mapping a story to a panel) is necessary to develop a data comics community. Overall, the warmup fulfilled its purpose as an icebreaker and enabled participants to start creating comics later in the workshop.

DISCUSSION

In the following, we draw out some of the themes that have arisen for us through the course of developing and working with the comics that we feel are of particular interest for designers of data presentations.

Current Design Pattern Collection

Our design space is a tool to help thinking about data comics and it may not capture all future design patterns. Additional aspects of data comics might lead to complementary and types of design patterns, e.g., visual-stylistic patterns, patterns about the usage of text, patterns for specific visualizations or data types, or higher-level patterns that structure entire stories.

Eventually, design patterns are tools to inspire creation but their respective effectiveness has yet to be assessed. While our workshop provides initial evidence that patterns can inform data comics creation, rigorous assessment of patterns is beyond the scope of the present paper as we believe it requires recruiting several data comic designers and performing a longitudinal study with them to understand how pattern may help draft and iterate on data comics. Data on effectiveness and usage might then allow guidlines for when to use specific patterns. Such guidelines need to consider the specific message to tell, the expertise of the audience, the type of data, etc.

Design Patterns for Teaching Visualization

Our workshop showed a general interest in and the usefulness of both data comics, storytelling, and our design patterns. We got approached by various university scholars to run extended versions of our workshop as part of their course curriculum (graphic design as well as computer science). For any future workshop we consider the following additions. We will ask participants to first draw their story on sticky notes or A5-sized papers to force them to think about important messages, explanations, and visualizations individually. Then we will ask to order and arrange the sheets and to think about necessary transitions (panels) and the narrative flow. Second, we need to emphasize the importance of text and textual narration as a strong point in data comics. We would ask participants to start from texts or to first write down their entire story before start sketching. All this require to extend the workshop, possibly over several weeks, addressing one comic making step at a time. While 3h allowed us to put the design cards on test, learning and iteration needs more time. Teaching material from the workshop is available online for own use.[6]

The design cards have been proven very useful, quickly helping workshop participants to engage with a new medium, with only little or no knowledge at all in visualization and comic making. The design patterns allowed our participants to draft both a story and a comic layout in a very limited amount of time. The resulting comics, though still drafts, showed that participants understood and internalized the design patterns and used them in their work. Concerns were raised that they might limit creativity, so some care needs to be taken in how and when the cards are introduced within a workshop. It is clear that there are more possibilities for data comic design patterns, as stated above.

We believe teaching data comics in visualization classes is an easy and cheap means to allow students to think beyond the pure visual encoding in visualizations; to think about the audience, the message, the purpose, the importance of the communicating the data as well as why to chose a specific visual representation/metaphor. Potentially, this could help put the practice of data visualization into a larger (social) context and may help participants develop a critical perspective towards the construction of data presentations and surface the questions of why particular structures are employed in different contexts and how to successfully communicate.

Data Comics for Data-Driven Storytelling

From carrying out these explorations, it became clear that data comics provide something distinct from infographics and other techniques for communicating data. While there is a broad application of known patterns, there is also a flexibility in the ways that material is treated and a rich reserve of structuring principles to draw on that aid understanding. In particular, formalizing common visual patterns in terms of comic layouts allowed us to identify some general strategies for visual storytelling and unexplored regions in this design space. The language of comics makes these patterns more explicit, facilitating the creation of complex data visualizations. Panels (whether explicit or implicit) can be used to break down the information into its fundamental units, and direct the attention of the reader. This direction, and an accessible narration style allows for a sense of *going along*, rather than presenting a pile of data, they are left with more agency, and a richer mental picture. Meanwhile, page layouts and flow marks reinforce both

[6] http://workshop.datacomics.net

linear and non-linear relationships between panels, guiding the reading and building narrative tension.

Every panel in a comic is a world within a world, and every page turn is a clean break. This gives data comics an incredible power to continually rewrite their presentational logic, creating ad-hoc axes, developing relations in unexpected ways and breaking their own rules at will. The comic in Figure 1 shows standard date and time axes deployed, but the panels that float inside them construct their own worlds with a logic of emotion rather than size and shape. This mutability of presentation gives data comics a great expressive range: every panel can have its own scale, structure, viewpoint and place within the next level of hierarchy. Data comics can draw on all of these and more, as they can make use of the data's semantics, contrasting explicit meanings to those created through structuring of the panels and their relations.

Data Comic Process and Tool Support

In contrast to traditional comics, there is no accepted practice for creating data comics. For example, while traditional comics employ steps such as story, narrative, characters, layout, and visual style, data comics involve the additional steps common to information visualization: data access, mining, stats, and visual mapping. As practiced in the workshop and as highlighted by Lee et al. [40] there are multiple approaches to creating data comics. For example, one may start from the raw data and identify findings, then figure out the story and later find the visualizations that fit both; or, one may start with a single complex visualization, an infographic, or a set of visualizations. Eventually, one may start with a question or story, retrieve the data and fit the visualization into the narrative. We imagine our design patterns helping at different stages of this complex process: identifying messages, structuring a story, or planning the layout. As data comics become more prevalent, more practices arournd making them will emerge.

While design patterns are fist and foremost a human tool (helping humans in their creative process), design patterns can inform and become part of future data comics creation tools. Creating data comics, currently involves visualization tools alongside with drawing tools such as Photoshop, Illustrator or InDesign. With our design patterns in mind, we can envision tools that provide design patterns, layouts, and flow-marks as templates. The editor could then allow to adjust panel size, content, etc. Interactive media may add more design patterns, capturing exploratory as well as explanatory aspects [55]. Design patterns or panel content could furthermore be suggested depending on the specific data and prepopulated, ready for manual layout. For example *spatial-annotations* for maps, *temporal sequence* for appropriate temporal data, *multiple-facets* for multivariate data. Eventually, this points to interfaces tailored for a rapid prototyping process, different interaction modalities [35], while providing seamless access to data visualization and publishing tools [39, 37].

Designing Beyond Genre Boundaries

Throughout this paper, we have held up data comics, infographics and data videos as examples of particular approaches to communicating both data and context. For all of their differences, many of the strategies that we outline here can be applied *across* different media. Figure 1 replaces the outlines of data elements with their pictorial content, as does Figure 9-right. This replacement of data point with content is not unique to data comics, and is increasingly used in e.g. exploring cultural collections [24], where combining the structuring logics of data visualization with the textures of the objects themselves gives a rich and compelling view onto large datasets. Similarly, the design pattern *zoom-in* can be executed in many different ways: a sequence of panels, a slow zoom in a video, a physical space that compels a viewer to walk gradually closer to a printed image [34]. While the underlying effect is similar, the manifestation is different, as are qualities such as the viewer's agency and whether all images can be seen at once.

We see data comics and the design patterns as an easy-accessible idea-creation space for data-driven storytelling and which can then be translated into other formats (genres). Moreover, we hope that our data comic design patterns, by talking about the relations between content, will support the development of communication patterns that can inspire other genres and media that make use of time, ink, pixels, interactivity and space—digital/physical, 2D/3D—equally well. This may lead to new hybrid forms for storytelling, including interactive web-comics, wall-sized walk-though comics, as well as interactive presentations.

CONCLUSION

In this paper, we introduced design patterns for data comics, a novel but scarcely explored genre. We demonstrated design patterns that assist in storyboarding data comics and developing about their expressiveness and potential. However, as comics combine aspects of communication through space and elements from temporal narration, the boundaries with other genres such as infographics and videos or presentations are somewhat fuzzy, thus requiring more research. Our patterns are inspired from and apply to other genres to some extent, while describing a common design space for presentation in data-driven storytelling. We believe data comics and our design patterns will inform future interfaces. They furthermore can change the way we conceptualize and create infographics and presentations, as comics provide a unique way of translating narrative practices and aspects from one medium to the other. Overall, we found data comics to be an engaging way to teach students about data, visualization, the art of storytelling, as well as the need for effective communication based on the evidence in data. We hope our patterns will help designers, data scientists, data journalists, and everyone else engaged in presenting data to create novel data comics and find new ways to express data.

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