6. Immersive Visual Data Stories

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Abstract. We discuss opportunities and challenges for making people experience immersion when interacting with visual data stories. Even though visual data stories are an important means for communicating information, the extent to which viewers feel immersed in such stories has so far been hardly explored. In this chapter, we explore the concept of immersion in visual data stories from the viewpoint of related disciplines in which narratives play an important role. We pay special attention to games research, which shares a focus on graphics and interactivity with our context of visual data stories. From this exploration we derive research opportunities and challenges for immersion in visual data stories.

Keywords: storytelling, immersion, data-driven narratives, narrative visualization, visualization

6.1. Introduction

Visual data-driven stories are a powerful means for communicating information to a broad range of audiences. Practitioners such as data journalists are increasingly creating popular data-driven stories that have been described as attractive, absorbing, engaging, or immersive. Examples include Hans Rosling's BBC performance [37] that has been viewed over eight million times on YouTube alone (as of December 2017). In the video, Hans Rosling narrates – with the help of active gestures, simple mixed-reality visuals, and a compelling script – the improvements of 200 countries in terms of average life expectancy and income over the past 100 years. This type of visual data story closely relates to movies and film in that the audience can watch but not interact but feels nevertheless "immersed" despite a lack of mouse or touch-based interaction.

Others have explored hybrid approaches allowing the audience to get involved in a scripted data story. For example, in "The Fallen of World War II" [20], a data story in the form of a narrated movie, the viewer can interrupt the story and interact with a chart that shows the deaths that occurred in WWII. With the advancement of mixed or virtual reality technology, practitioners have also started to tell stories by incorporating or mimicking real and virtual worlds. In 2015, Roger Kenny and Ana Asnes Becker (working for *The Wall Street Journal* at the time), for example, created a Virtual Reality (VR) visualization tour of

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the financial crisis of 2007 [25]. This story uses a roller coaster metaphor to convey the variation of the stock market value; the viewer is sitting on a virtual carriage on top of the ridge of the stock market values and follows the narration as the carriage moves forward in time. The ride starts during the pre-2000 boom and goes up and down through the chart from March 10 2000, when the Bubble Bursts, to November 2015. At this point, the ridge is very thin, reflecting low share prices. The ride continues with a big fall and passes through the terror attack of 2001 and rides to 2015. The authors aimed to create a data story that conveyed the data by evoking different feelings and experiences in the viewers [6]. The story unfolds as the viewer moves forward in time but stops at key moments on the Nasdaq variations. As in this piece, it is relatively common that immersive journalism uses 360° videos to immerse their audience into a documentary. The aim of such techniques is to provide the audience with an auditory and visual experience that evokes people's belief to be *within the situation*.

While these visual data stories above, as well as many others, have been described as immersive, the exact characteristics of an immersive data story remain elusive. In particular, it is most often not even clear what the experience of immersion into a data story would encompass. Do immersed viewers lose their sense of time when consuming data stories, feel particularly connected to the data, feel more broadly engaged, start to care about the data more, or any combinations of characteristics that have in the past been associated with an immersive experience?

While researchers and practitioners are actively exploring the challenges and opportunities of narrative visualization, the challenge of creating an immersive data-driven story or narrative has so far received very little research attention. Yet, the concept of immersion has been extensively discussed in the context of different storytelling media. Unfortunately, these discussions often use different meanings and definitions of the term immersion itself, which leads to confusion with related terms including presence, engagement, perception of realism, addiction, suspension of disbelief, and flow [14].

In this chapter, we discuss how we can understand immersion in the context of visual data stories after briefly describing related work on storytelling with data-driven narratives. It is important to note that in these discussions we do not focus on any specific technology such as virtual or augmented reality. Instead, we discuss immersion as a concept that involves cognitive and emotional involvement, and derive a set of goals and research challenges based on this view of immersion.

6.2. Visual Data-Driven Stories

Data-driven storytelling–also called narrative visualization–has become an active research direction within the domain of visualization [40]. Specifically, instead of focusing only on providing means for effective exploration and analysis of data, narrative visualization concerns effective explanation and presentation of data using visualization. The goal of visual data-driven stories (in short, visual data stories) is generally to reach a wide or targeted audience by putting together visualized findings or messages with connections such as temporal or causal relations [27, 29]. In the past, there have been conceptual and theoretical research papers on the topic, work on specific storytelling techniques and methods, as well as work dedicated to specific storytelling genres or data types.

6.2.1. Understanding Data-Driven Narratives

Dedicated research on storytelling with visualizations does not yet have a very long tradition. In 2010, Segel and Heer presented the first systematic study of the design space of narrative visualizations and categorized different genres, design elements, and narrative structures [40]. Similarly, the work by Hullman and Diakopolous focused on describing techniques for communicating an intended message with a visualization – with a focus on visualization rhetoric [22]. Both of these papers did not use a clear definition for a "visual story" or "data-driven visual narrative," a point critiqued later by Lee *et al.* [29].

In their work, Lee *et al.* looked more closely at the process of creating data stories. The authors began by proposing three defining characteristics of a visual data story: visual data stories must include a set of facts backed by data (i. e., facts must be data-driven), most of these facts must be visualized to support an intended message (i. e., representation must be visual), and the visualization must include a meaningful order or connections that support the intended message (i. e., a story). As such, the presence of underlying data, an intended message, and a logical collection of supporting visualizations are key to distinguishing a visualization that is meant to tell a story from others that are meant to be used primarily for exploration and analysis. Lee *et al.* then proposed a working model for visual data storytelling process consisting of three main phases – explore data, make a story, and tell a story – to encompass the entire process of transforming data into visually shared stories. Chevalier *et al.* [15] later revised Lee *et al.*'s process grounded by interviews with nine professionals who create visual data stories. The authors identified new roles including data collector and director as well as additional external factors including time and ethics.

Researchers have also studied existing visual data stories to derive insights helpful for developing storytelling techniques and authoring tools. To better understand the effect of sequences in narrative visualization in order to develop an automatic sequencing algorithm, Hullman *et al.* conducted a focused analysis of transitions between scenes in 42 linear, slide-show-style presentations [23]. Stolper *et al.* [43] performed a qualitative analysis of 45 popular data stories and identified 20 data-driven storytelling techniques grouped under four categories: Communicating Narrative and Explaining Data, Linking Separated Story Elements, Enhancing Structure and Navigation, and Providing Controlled Exploration. In proposing the concept of "visual narrative flow," McKenna *et al.* [32] systematically investigated 80 stories found on popular websites, and identified seven "flow-factors" that can shape the flow of visual data-driven stories: navigation input, level of control, navigation progress, story layout, role of visualization, story progression, and navigation feedback.

6.2.2. Techniques and Authoring Tools for Data-Driven Visual Stories

Several researchers have proposed design considerations for visual data-driven stories of a particular style or for particular types of data. Amini *et al.* [1], for example, systematically studied 50 professionally designed data videos to understand the structure and sequence designers commonly use to construct narrative visualization. After that, through a further analysis of an extended set of data videos, Amini *et al.* [2] identified a library of data clips that cover major components for creating compelling data videos. Similarly, Wang *et al.* [46] studied the use of animated narrative visualization for the presentation of video clickstream Data. Animation can also be used to highlight critical information in data stories. For example, Waldner *et al.* [45] studied how to guide the audience's attention through a flicker in dynamic visualization.

Bach *et al.* [3] studied comic-strip-style narrative visualizations to show changes in dynamic networks. The authors propose eight different design factors for creating this particular type of visual story, involving, for example, the visual representation of graph items, changes over time, or characters. Brehmer *et al.* [9] performed a survey of 263 timelines to identify a design space for storytelling with timelines. The authors show that 20 combinations of 14 design choices lead to viable timeline designs that can be integrated into visual stories together with smooth animation.

While the research presented above mostly focused on survey-style or theoretical contributions for proposing design considerations for data-driven visual stories, several others focused on contributing authoring tools. For example, Lee *et al.* [30] introduced a new storytelling system, *SketchStory*, a data-enabled digital whiteboard that extends the narrative storytelling attributes of whiteboard animation with pen and touch interactions (Figure 1).

Hullman *et al.* [21], for example, described a technique, *contextifier*, that focuses on the generation of annotated charts. By analyzing a set of news articles related to the chart, contextifier can generate narrative visualization in an annotated chart style. Similarly, Ren *et al.* [35] focused on chart annotations in their survey of 106 annotated chart images published by prominent news graphics. The authors' survey led to the design of a system *ChartAccent* (Figure 2) that helps authors quickly and easily augment basic charts through a set of annotation interactions that generate manual and data-driven annotations. Wang *et al.* [47] proposed a narrative visualization system that helps researchers read academic papers by turning research paper into interactive slides.

Researchers have also started to investigate ways to integrate exploration and presentation processes in narrative visualization tools. Gratzl *et al.* [19] propose the CLUE (Capture, Label, Understand, Explain) model that allows people to create a visual data story based on the history of the exploration; they can extract key steps, add annotations, and construct a story using the provenance data captured during the exploration process. Bryan *et al.* [12] present an approach that automatically creates and ranks data-driven annotations during the analysis to help people synthesize a coherent narrative with a temporal data summary.

Fig. 1: SketchStory attracts attention and creates anticipation using a real-time approach to content creation with pen and touch interaction.

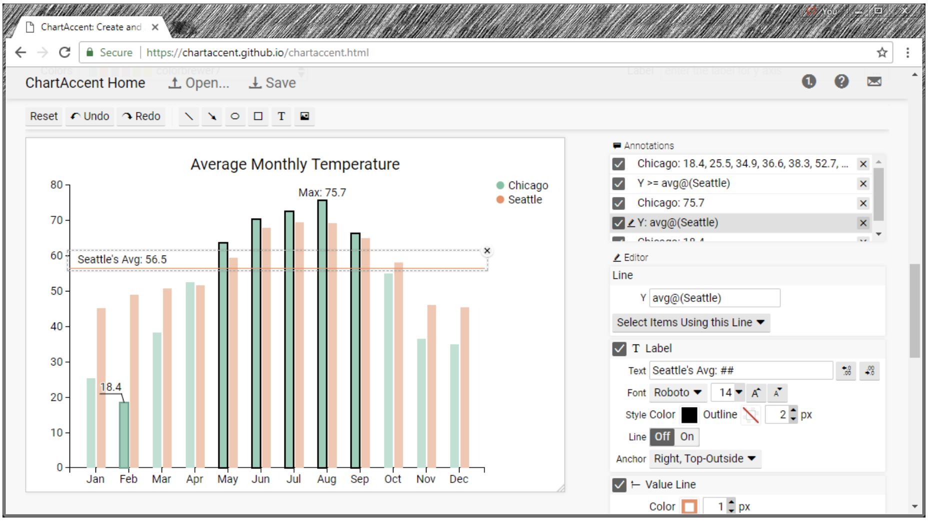

Fig. 2: ChartAccent is a web-based authoring tool that enables people to augment charts using a palette of annotation interactions.

Due to the popularity of infographics, we are seeing an emergence of tools to facilitate their creation. Kim *et al.* [26] presented Data-Driven Guides, a technique to enable designers to generate guides from data and use them to accurately place and measure custom shapes. Hanpuku uses a bridge model that allows designers to bring their work back from the drawing tool (e. g., Adobe Illustrator) to re-edit in the generative tool (e. g., using D3 scripts) [7].

Researchers have also developed authoring tools to enable people with little or no programming skills to create a narrative visualization that supports interactions and animations. *Ellipsis* helps storytellers generate narrative visualization using templates with a domain-specific language (DSL) and a graphical user interface [39]. *TimeLineCurator* automatically extracts temporal events from freeform text and enables people to interactively curate the events, helping them easily generate a linear timeline [18]. DataClips is an authoring tool that helps non-experts create data videos [2]. Timeline Storyteller (Figure 3) allows people to present different aspects of timeline data such as chronology, sequence and the periodicity of events using a palette of timeline representations, scales, and layouts, along with controls for filtering and annotation [10].

Fig. 3: Timeline Storyteller enables people to create a scene-based story, presenting different aspects of timeline data using a palette of timeline representations, scales, and layouts. It provides people with controls for filtering, highlighting, and annotation.

6.3. Defining Immersion in Visual Data Stories

In the previous section, we introduced a large number of projects dedicated to narrative visualization or the creation of data-driven visual stories. None of these papers have specifically focused on immersive data-driven stories – in the general definition of immersion that we use in this book. So let us now more concretely discuss what we exactly mean by an immersive visual data story.

In previous work, the term immersion has been used with various definitions depending on many factors such as the type of media referred to, the research domain, or the individual researchers who used it [14]. Much of this past work, however, has in common that immersion refers to a specific phenomenon that describes the experience a person has when engaging with a specific medium, such as a book, a movie, or a game. Immersion in the domain of visualization – narrative visualization in particular – has, however, not been clearly defined as a term that describes an experience. When "immersion" is used with the term "visualization" it most often refers to the fact that 3D visualizations are generated for viewing in virtual reality environments (e. g. [17, 28, 44]) and the focus of the work is more technical on how to achieve smooth renderings for these more complex technical setups or a multi-sensory experience. For example, previous work has investigated how virtual reality technology affects persuasion in data-driven storytelling [5]. The definition of immersion used in this paper followed Sanchez-Vives & Slater as [41]: "the technical capability of the system to deliver a surrounding and a convincing environment with which the participant can interact." No evidence was found in this paper to support the benefits of using an immersive environment given this definition.

We argue here, that this narrow view of immersion in visualization misses to point out many design opportunities and does not help us explain why some visualizations may capture viewers more than others. Before discussing how we use the term in this chapter and describing the experiences an immersive data story may want to create, we will take a look at the difficulty of defining the term in a related discipline: games research. We chose to focus on this particular context as it shares several characteristics with the specific data storytelling environments that we are ultimately interested in: both games and visual data stories are interactive and inherently graphical, they (often, but not always [13]) attempt to engage the player/viewer in a narrative, involve either open-ended or prescribed tasks to be accomplished that are often challenging, and mostly focus on non-stereoscopic presentation outside of VR – a technical focus we want to avoid in this book chapter. By relating our definition to games research, we do not, however, exclude experiences such as the Hans Rosling and Fallen of WWII examples described in the introduction, which both are less interactive and more movie-like. We will describe these data-driven stories using the same definition of immersion that we will choose for more interactive and open-ended data stories.

6.3.1. Immersion in Games

For games research, Calleja [14] discusses how the almost interchangeable use of the terms *immersion* and *presence* has been detrimental for research. The author details the varying uses of the term and proposes to distinguish between the *absorption-sense of immersion* and *transportation-sense of immersion.*

The *absorption-sense* of immersion refers to what Lombard and Ditton [31] call "psychological immersion:" a sense of involvement, absorption, engagement, and engrossment in a game. For example, someone could become fully absorbed in playing a simple game such as Tetris – or one could say "immersed" in the absorption-sense of the term.

In contrast, the *transportation-sense* of immersion refers to viewers, readers, or players feeling they have been transported into a different world. This sense of transportation can be graphically created or internally generated, for example, when reading a story. A game such as Tetris, for example, cannot provide immersion in the transportation sense since its game world is not meant to be spatially navigated and besides the falling building-blocks, no other game objects can react freely to the player's actions. Thus, the capability to provide immersion as transportation is effectively different for different media. When readers feel transported into the world of a book, this world does not provide feedback. An interactive storytelling medium, on the other hand, can provide a very different form of transportation by reacting to a user's actions.

Brown and Cairns [11] added an important aspect to the discussion of the term immersion by introducing three degrees of immersion: engagement, engrossment, and total immersion. According to Brown and Cairns, players first need to invest time, effort, and attention to become engaged and interested in a game to want to keep playing. As immersion increases, players can become engrossed in a game. They become less aware of their real surroundings and establish an emotional connection to the game. Plots, tasks, and visuals are particularly important to create a sense of engrossment [11]. Brown and Cairns equate total immersion, the most highly immersed state of a player, with the term presence, a situation in which one feels completely present in the game world and reality and sense of time are cut off. Similar to engrossment, total immersion includes an emotional component–empathy and attachment with game characters–and a technical and storytelling component: atmosphere, which includes the graphics, plot, and sound of the game. Calleja [14] argues that Brown and Cairns [11] merge the absorption and transportation senses of immersion. Both engagement and engrossment follow the absorption-sense of immersion while total immersion uses the transportation-sense of immersion. Cairns *et al.* [13] themselves state in a later book chapter that equating presence with total immersion was confusing as presence and immersion are not the same. They now more simply describe immersion in a game as "the engagement or involvement a person feels as a result of playing a digital game." The authors, in particular, describe immersion as a cognitive and emotional state or experience that players achieve which makes them feel like they are "in the game." The distinctions between presence and immersion are further complicated by the fact that the term "presence" is not coherently used in the literature either [14, 42].

Yet, Calleja [14] agrees with previous work that immersion is not a single experience that can be easily measured and it is never just present or not, it exists on a continuum and is the result of various forms of involvement with a medium. These forms of involvement, Calleja [14] argues, must be understood first before immersion can be studied. He proposes that immersion, together with a sense of transportation (presence), is a component of the larger concept of incorporation; incorporation describes how a player incorporates/assimilates the game into their consciousness and at the same time becomes incorporated into the game world as an avatar. Calleja goes on to distinguish and discuss six dimensions of involvement: kinesthetic involvement (control of character or game pieces), spatial involvement (navigation, exploration), shared involvement (with other game agents), narrative involvement (with story elements), affective involvement (emotional engagement), and ludic involvement (making game choices). One or more of these types of involvement can together be precursors to the experience of immersion. Cairns *et al.* [13] argue that there is another precursor to the first level of immersion that was missed in Calleja's work: the external context of playing the game such as the room the game is played in. This argument is based on the results of a study in which the authors found that physical lighting conditions, for example, influence the experience of immersion.

In summary and most importantly, however, Cairns *et al.* and Calleja both describe immersion from an experiential perspective and as an experience that includes different levels of involvement and cognitive absorption.

Others have proposed types of immersion that are more closely related to narrative or storytelling. Games research, similar to visualization, has controversial discussions about the role of narrative. Adams [6] previously proposed consideration of three different types of immersion, one of which he called narrative immersion (the other two being tactical and strategic immersion). According to Adams, a player has reached narrative immersion when he or she starts to care about the game characters and wants to see the end of the game story. Important precursors to such immersion in a narrative are a good plot, dialogue, and believable or relatable characters. As such, narrative immersion is closely related to the emotional involvement with a game mentioned by Cairns [13]. Similarly, Calleja [14] argues that one reason games are often extremely absorbing is that they affect players' emotions. In addition, Calleja [14] discusses narrative involvement as a pre-cursor to immersion and tries to understand how narrative is experienced in game environments. Calleja proposes to distinguish between the *alterbiography*, or the story generated by the player as he/she interacts with the game, and *scripted narrative* which are the scripted story events that the game designers included in the game. In citing Iser's work [24] Calleja brings up the concept of (internal) *synthesis* which describes how a reader/gamer/user of any representational medium forms a mental image of their experience with or understanding of the medium. Synthesis, thus, becomes an important part of experiencing a game narrative. In addition, when players are kept wondering "what will happen next?" or "what will happen when I make a certain choice" they may become quickly engaged with a scripted narrative and their current alterbiography.

In contrast to the ways of discussing immersion presented above, immersion can also be described as closely related to the concept of presence in a virtual environment. Some definitions of presence relate closely only to the availability of sensory input and output parameters. Zeltzer [48], for example, referred to it as a "lumped measure of the number and fidelity of available sensory input and output channels" – which is a much more technical definition than the "feeling of transportation" that other parts of the literature use. Slater [42] also argues that immersion reflects technical capabilities of a system: " The more that a system delivers displays (in all sensory modalities) and tracking that preserves fidelity in relation to their equivalent real-world sensory modalities, the more that it is immersive." Presence, for Slater, on the other hand, is the human reaction to immersion. Slater's proposal seems to be widely adopted in the VR literature and is also sometimes referred to as "perceptual immersion" [31]. It is also the sense in which immersive visualization is most often used (e. g., [5]).

Cairns *et al.* [13] also discuss definitions for presence and their relationship to immersion in detail. The authors specifically differentiate between social presence and spatial presence. Social presence is defined by social factors of the game environment (the social character of the interaction, the feeling of being a social actor in the environment, and social actions/reactions from the game environment) which relate to the concept of a narrative or story. Spatial presence, on the other hand, includes a sense of realism of the virtual environment, a sense of transportation into the game world, and sensory immersion, which is a more technologically oriented view on presence. The authors conclude that "immersion is influenced by social presence but not necessarily by spatial presence" in particular since they define immersion as a cognitive phenomenon.

6.3.2. Immersion in Visual Data-Driven Stories

Unfortunately, researchers do not yet know much about how models of immersion from games (or other) research transfer to visual data-driven stories. As discussed above, there are similarities between the two environments, in particular their primarily graphical nature, ability for interaction, and possibility for communicating a narrative–but there are also large differences. Viewers of a visual data story, for example, typically will not approach a visualization with the same incentives and goals; they will consequently have different expectations and preconceptions of a visualization than they would of a game. The two most important differences are, however, the frequent lack of a central character in a visual story to identify with and the story's data being frequently based on not alterable non-fiction in contrast to the narratives of games that–even if based on historical events–can typically be influenced by the player to deviate from what truly happened in the past (changing their alterbiography). As such, we can be inspired by the discussions of immersion in game narratives when trying to define what it means for visual data stories but the relationships will be non-trivial.

In general, the main goal for constructing a data story in the first place is effective communication of information or an intended message backed by data. We do not know how an immersive experience would affect the perception and retention of the depicted information. In order to begin studying the effects of immersion or designing for immersion, we need to be clear about the definition of immersion for data-driven visual stories. Following our discussions from above, we will begin by considering what it would mean if we considered immersion for visual data stories using the absorption- or transportation-sense of the term.

Describing immersive data stories in the transportation-sense would require the data story to be spatially navigated or interacted with in an almost physical (or pseudo-physical) way. A few visualizations exist that allow this type of experience but generally, they are rarely built, distributed, and adopted.

The roller coaster example from the Introduction Section is one example of a visualization that has been specifically built for storytelling and an immersive experience in the transportation-sense. There has been little past work on how setting up these types of environments affects a potentially immersive experience of a viewer or user.

If we discuss immersive data stories using the absorption-sense of the term, we expect an immersive data story to engage and involve viewers or users to different degrees in the data story. These types of data stories can be two-dimensional visualizations found in online journalism, blogs, or newspaper articles, similar to the examples surveyed in the past [32, 40, 43]. Past research on narrative visualization has to a large extent focused on these types of data stories. Understanding immersion according to the absorption-sense will ultimately require understanding how a viewer (or "user" if the stories are designed for interaction) cognitively experiences or synthesizes their experience with a narrative visualization. This experience, unfortunately, is something researchers still know very little about. Past research (see Section 6.2.) on storytelling with data has to a large extent considered the means by which a story can be communicated with data or the process by which data-driven stories can be created and largely only conjectured on the effects of storytelling elements on effective communication. The related work on immersive virtual reality visualizations has, perhaps, put the most emphasis on creating a specific absorption experience – primarily through effective rendering techniques and sensory input. However, as we discussed above, many more factors than the display environment can contribute to an immersive experience according to the absorption-sense.

Previous research on immersion in narratives in other disciplines has, in addition, considered what makes a narrative immersive and even attempted to measure immersion. Qin *et al.* [34], for example, take narrative as a broad term in their work on a questionnaire for measuring immersion in game narratives. Their questionnaire includes seven dimensions of questions, three of which are targeted specifically at user immersion in the absorption-sense: comprehension of the structure and content of the story/plot, empathy or a feeling of being in the game world or emotionally involved in the game, and familiarity with the game story. The other four dimensions seem more targeted to measuring precursors to immersion: curiosity to explore the game narrative, concentration on the game, challenge and skills offered and required by the game, as well as a sense of control over the game narrative.

Outside of games research, several authors have tried to extract what makes other types of media narratives immersive. In “The Art of Immersion” [36], Rose discusses how media has been changing and evolved to form new types of narratives and immersive experiences. The type of immersion he describes is different from the ones we discussed above. Rose, in particular, refers to new methods for readers to engage deeply with stories that have previously not been interactive. His book includes many examples of movies such as Star Wars that describe a whole universe – which through books, games, websites, etc. can now be experienced deeply outside the original medium – the movie theatre. For Rose, immersion in a narrative can be reached by giving viewers the ability to “drill down as deeply as you like about anything you care to” [36, p.3].

In her work on “Narrative as Virtual Reality” [38], Ryan explores theories of immersion for literary texts. She shows that the concept of immersion as “feeling like one is part of another world while reading” has been discussed by authors and literary scholars for a long time for narrative texts. For such an immersion to take place while reading, the text must offer a “textual world” that readers can imagine as a reality with objects and characters and build a mental model of. When a reader feels transported into the world of a book, the textual world becomes present in the mind of the reader. How well this representation can be established depends on many features of the text such as its plot, the narrative presentation, images, and style; but it also depends on how effortlessly the world can be accessed or how much concentration is necessary. Ryan further distinguishes four levels of absorption in a text: concentration on the text while still being easily distracted, imaginative involvement where the reader follows the narrative but still is able to assess the author’s writing skills, entrancement in the textual world and minor dissociation from the physical world, and addiction in which the reader devours a book without assessing it while being completely dissociated from the physical world.

At this point we have seen that immersion is an elusive concept. It is an emotional and cognitive experience, with multiple levels of involvement and many influencing factors. Given how others have attempted to define and describe immersion or immersion in narratives above, we can now begin by describing a set of goals we may want to achieve by an immersive visual data story. The following list is meant to expand upon other similar immersive experiences that can be evoked by a visualization or analysis environment – such as dissociation from the presence or feeling of being “in the data” – see for example Chapter 1. Concentrating solely on immersion in a data story, we may want to achieve:

- A feeling of being closely connected to the data story and its intended message.
- An emotional reaction to the message. This emotional reaction can be a positive or negative one, including anger or sadness about the depicted content, or a feeling of surprise and joy about the data;

– An urge to deeply explore and "get lost" in the data story, a deep engagement or engrossment with the components of the data story.

Given what we have reviewed above, we advocate to take a wide view of the term immersion in visualization and follow Cairns *et al.* [13] in proposing a wide definition for the field of visualization: *Immersion in visualization is the engagement or involvement someone feels as the result of looking, exploring, or analyzing a visual data representation.* Given their goals and ours, we propose to, in particular, consider immersion in visual data stories as an experience that involves a sense of *absorption* leading to deep involvement, engagement, and engrossment with the data. Many additional factors discussed above can lead to this kind of immersion, such as a social presence, internal synthesis, emotional connection, or a feeling of transportation into the data-world. It will have to be explored which factors influence immersion in visual data stories and the list of research projects to engage in this realm is still vast.

6.4. Research Opportunities in Immersive Visual Storytelling with Data

The three goals listed in the previous section are central to what immersion in visual data stories can aim to achieve but other goals are certainly possible. In this section, we describe several opportunities and challenges that arise when we want to design immersive visual data stories that achieve these three goals. We present what we believe to be some of the most interesting research questions on this topic, but many more are possible and our list is certainly not complete. Each research question posed is also purposefully broad leading to a wide number of possible future research projects.

How much reality is necessary? Traditional definitions of immersion in the field of virtual reality have focused on immersion from a technological perspective, focusing on creating sensory experiences that are as close as possible to the real world and involve more than the visual sense and include audio or even tactile stimulation. Game development similarly has long striven for realistic graphics, sound, and character animation. Yet, as we have discussed immersion above, realism might not be necessary for people to become immersed in the absorption-sense of the term. When a game like Tetris can be described as immersive, so should a 2D infographic have possible immersive capabilities. When we move away from realism as a purely sensory experience we may ask the question what other "real" elements a 2D visual story could incorporate to make the experience of looking at or interacting with the data more immersive? For example, the Hans Rosling example from the Introduction included a real narrator, the Fallen of WWII included references to real-world characters as well as voice narration, and the roller coaster example had the viewer virtually following up-and-down movements with the up and downs of the financial data.

Perhaps storytelling elements that make connections to the "real-world" or the context of the data can help to make visual data-driven stories more immersive?

For example, many infographics contain images related to the context of the data, such as the four images of baseball players in the New York Time's piece on steroid use in baseball: "Steroids Or Not, the Pursuit is On" reprinted by Segel and Heer [40]. Past research has shown that some form of embellishments to data charts can be helpful, e. g. for memorability [8]. Yet, how embellishments such as images, or pictograms can aid in storytelling and immersion has not yet been deeply researched. In addition, many other forms of connecting abstract data to the real-world data context are certainly possible as described in the three examples from the introduction. Which connection techniques exist, how and if they are effective, and what kinds of immersion they support will be a challenging but undoubtedly interesting research problem to tackle.

What is the role of the visual storytelling medium and context? Visualizations can be shown using many different media: visualization can be printed on paper, shown on computer screens, projected on physical environments, or printed into 3D physical shapes. Related to the question of realism above, it is interesting to understand to which extent the presentation medium and its physical context play a role in creating an immersive experience. Previous work has shown that context such as lighting can play a role in facilitating immersion. To which extent would the same be true for visual data stories? Also can, as previously conjectured, different types of displays such as large displays or CAVEs aid immersion in a visual story? Even if their goal is not to necessarily create a feeling of physical realism?

What is the role of interaction in creating or hindering immersion? Many experiences described as immersive in other media such as watching a scary movie or reading a captivating book require little interaction from the viewer. Rose's [36] discussion on immersion by "drilling down as deeply as you like on anything that you care to" is related to this question of the role of interaction for immersion–and in particular the type of cognitively absorbing experience that we focus on here. In his book he looks at interaction as a more global concept that involves viewers or fans creating content of their own (such as the Lostpedia[5] for the TV series Lost) or adapting and remixing content from their favorite shows. As Rose points out, this type of interactivity with the content has the advantage of people becoming experts on the content but also allows the audience to run away with a story and change it as they please. With a data-driven story this is potentially dangerous as it may allow people to insert rumors, personal beliefs and other non-data-driven content around an existing data story.

Yet, the role of interaction can also be considered at a much lower level for individual data stories in which the type of interaction techniques need to be considered (e. g. mouse vs. touch), how much of the data can be manipulated, or which interaction hardware will be offered. Data visualizations often offer interactive capabilities to help people drill down on details that interest them. This type of free exploration can both help in creating an immersive experience of "getting lost in the data" but it can also break an emerging immersion when people have to search for interactions or cannot find their way back from detail

[5] http://lostpedia.wikia.com

views and undo their past exploration steps. What the right balance between fully interactive experiences, guided walkthroughs, or no interaction at all is for the creation of an immersive data exploration experience is so far unclear.

How can we emotionally involve viewers? As discussed above, an emotional reaction to a visual data story can be an important pre-cursor to immersion. Yet, how a deep emotional connection can be achieved for visualizations and in particular for data-driven visual stories is yet unclear. It can become in particular difficult since visualizations–unlike games–typically do not include specific characters that viewers/users can attach to or feel empathy with or a "world" that they can be part of. It also needs to be considered what kinds of emotions one might want to evoke in the first place. For example, we may want to create feelings of empathy when showing data on deaths, fear when seeing visualizations of the results of climate change, joy in seeing personal visualizations of past travels, surprise in how much money the government spends, anxiety to change behavior when seeing one's own energy consumption, or pride when looking at personal visualizations of fitness data.

Emotions are a very complex phenomenon and so studying the role of emotion for immersive data-drive visual stories will be challenging. Past work on memorability [8] or sustainability/persuasion [33] have laid some groundwork for studying concepts related to emotion and immersion in visualization. Recently, Bartram *et al.* [4] studied affective color for visualization which is one step towards design elements for visualizations that can influence visual storytelling with data. More dedicated work in this direction could re-examine already proposed storytelling techniques for visualization and their potential influence on emotion, for example, how can the presentation of annotations lead to emotional involvement, would fonts, font sizes, and the type of writing influence how people emotionally react? Similarly, other storytelling techniques could be re-examined.

What are levels of immersion in visual data stories? As discussed above, immersion is not a binary experience that is either present or not. Immersion has been described as an experience along a continuum, for example, from people feeling simply engaged, to feeling fully absorbed in the medium. It is not clear to which extent this continuum will be present in immersive experiences around data visualization. Which past definitions of the immersion continuum would most relate to how people experience visual data stories? Would Brown and Cairns' [11] engagement, engrossment, and total immersion in games research make sense to apply? Or would Ryan's [38] immersion continuum from concentration, imaginative involvement, entrancement, to addiction in literary texts make more sense? In general, more research is necessary to see how concepts of immersion from other research fields apply to visual stories. While we have outlined a large body of past work on the topic in games as well as a few discussions from other fields in this book chapter, the remaining literature is vast and certainly more can be extracted and learned from it. For the visualization practitioner, the most useful goal will be to derive design considerations for immersive visual stories. In addition to theoretical assessment of the remaining literature, it is, thus, important to derive ways for measuring immersion.

What are the effects of immersion on the viewer? All research questions above hinge to some or even a large extent on the question of how to measure immersion for visual data stories. Some related work has attempted to study immersion through questionnaires, and there is related work in brain-computer interfaces that has looked at studying components of immersion such as concentration or emotion/affect (e. g. [16]). This past work may be a good starting point to attempt to measure immersion in visualization before more dedicated research methodologies can be developed or adapted from existing techniques. Studying immersion is important as many interesting questions are open as to the effects of immersion on the viewer. Will an immersive visual data story aid visualizations to be more memorable, will viewers retain more information, will they learn better, will they be better persuaded to act? In addition, the research questions raised above hinge to a large extent on the possibilities to measure immersion.

What are potential dangers for immersive visual stories? Finally, it is not clear to which extent it is even desirable to create an immersive visual data story. If viewers become so immersed that they stop to question the data, where it comes from, and what it might want to say, this can be potentially dangerous. In addition, it is possible that people want to make a visual story their own and synthesize it as they please. Could immersion help to lead people on the right path? Or drive them down even further in the wrong direction? In addition, attention has to be paid to the blurring of fiction and fact in particular when specific storytelling elements are added to potentially create immersion but which hinder the interpretation of the data. In general, negative side-effects of immersion have to be considered side-by-side with measuring positive effects of an immersive experience.

6.5. Conclusion

Visual data stories bring us a powerful means for communicating information to a range of audiences. In this chapter, we discussed immersion in the context of visual data stories. We first presented an overview of how immersion has been discussed in the related literature, focusing on a definition of immersion for visual data stories that is inspired by previous descriptions of the absorption-sense of immersion. We propose to begin research on the concept of immersion in visualization with a broad definition: *Immersion in visualization is the engagement or involvement someone feels as the result of looking, exploring, or analyzing a visual data representation.* This type of immersion can involve many factors such as a deep sensory experience in VR environments, an emotional connection to the data and its main message, a feeling of social presence, or even transportation into the data world. Not all of these factors will be necessary to create this feeling of immersion and much research has to be conducted to understand the role of these and other factors in creating immersive data visualization experiences. In this book chapter, we focused in particular on challenges and opportunities for immersive data stories. We hope that our work will inspire others to start their own projects in this direction as the research questions on this topic are still wide open.

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