

Why, What, and How to Communicate Health Information Visually: Reflections on the Design Process of Narrative Medical Visualization

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Abstract

Narrative visualization is an effective technique to convey information to a lay audience in an engaging, memorable, and persuasive manner. In the medical domain, we experienced that narrative medical visualizations meet high interest from clinicians and epidemiologists as storytelling is a promising approach to conveying complex medical topics in the context of patient education and public health by utilizing medical data. These endeavors from the computer science domain are mirrored by the interdisciplinary research topic of health communication. With this work, we reflect on our past experiences by (1) showing where narrative medical visualization is applicable to solve problems clinicians face in their work, (2) summarizing all findings within a story design process, describing the key points in creating a story and how they relate to each other; and (3) highlighting parallels and insights from health communication research that can improve future narrative medical visualizations. In doing so, we aim to provide the research community with a toolkit to support the design of narrative medical visualizations.

CCS Concepts

- *Applied computing → Life and medical sciences;*

1. Introduction

Narrative visualization, which combines data visualization with a narrative, is particularly valuable for communicating with lay audiences. We applied this technique in the medical domain, where it generated substantial interest among various stakeholders. In particular, clinicians highlight the potential of this approach to improve patient education and public health initiatives through the use of medical data. For example, there is little time for patient education in a clinical setting, and health literacy is generally low, despite the need to involve patients in decision-making. The computer science community's efforts to develop narrative medical visualizations align closely with health communication research which focuses on designing messages that persuade audiences to adopt health-improving behavioral changes. Informing lay audiences about health issues while considering their level of health literacy empowers them to make informed decisions about their personal health [IK10].

We reflect on our experiences in creating narrative medical visualizations in collaboration with clinical partners. We focus on (1) identifying relevant application cases, (2) introducing a story design process (Figure 1), outlining key points in creating medical stories and elucidating their interrelations, and (3) examining our experiences through the lens of health communication to understand how narratives can be improved to increase their impact. We seek to contribute to the ongoing dialogue on the integration of narrative visualization and health communication to advance public health objectives and guide the design of future visualizations.

2. Related Work

Narrative medical visualization focuses on engaging lay audiences through the use of data visualizations, while health communication examines how to design messages with maximum impact on their audience. Although health communication encompasses a broad range of strategies, the use of visuals is a specific subfield where it overlaps significantly with data-driven medical storytelling. We focus on the work most relevant to our manuscript, but there is much more research available on narrative visualization.

2.1. Theoretical Concepts of Narrative Visualization

Narrative visualization and data-driven storytelling are often used interchangeably in scientific publications. While we will retain the manuscripts' original terminology for the related work section, we will use *narrative medical visualization* as a term to describe the technique and *narrative* for individual stories for our own work. Brent Dykes [Dyk19] describes several techniques to transform data into stories. In particular, he claims that to build a story four ingredients are needed: *Conflict*, *Content*, *Characters*, and *Structure*. Fog et al. [FBMB10] discuss storytelling for defining a brand in a company setting and define four elements of storytelling: *Message*, *Conflict*, *Characters*, and *Plot*. Two of the elements, *Conflict* and *Characters*, overlap with the ingredients from Brent Dykes. Another element called *Plot* is similar to *structure*. In a research setting, Bach et al. [BSB*18] defined patterns for data-driven storytelling, claiming these patterns can be applied when the following requirements are

met: having a *story*, *target audience*, and *intended effect* on the target audience. Lee et al. [LRIC15] introduce a visual data storytelling process highlighting different stages of transforming data into stories as well as roles that need to be played by one or more persons, i.e., data analysts, scripters, editors, presenters, and audience. We found many parallels between these theoretical foundations and our practical experience in implementing narrative medical visualizations. Therefore, we draw on these foundations and combine them with techniques from health communication to present a pipeline for creating narrative medical visualizations.

2.2. Health Communication

Communicating medical data to a lay audience to facilitate behavioral change is the core motivation for public health. Studies show that properly designed public health media can motivate behavioral change [NIYM22]. Nan et al. [NIYM22] present three major types of health message executions: narratives, visuals, and emotions. Positive (i.e., fear and guilt) as well as negative emotions (i.e., hope and compassion) can enhance the effectiveness of a health message. It is important to note that the goal of health communication is not to manipulate, but to empower audiences with varying levels of health literacy to make informed decisions about their personal and public health [IK10]. Two important aspects in health message design are the *message content* ("what to communicate") and *message executions* ("how to communicate") [NIYM22]. How to design an effective public health message to motivate behavioral change depends on the personal orientation of each individual. Therefore, it is not possible to define a single most promising strategy. Nan et al. [NIYM22] have identified three main factors for behavioral change in the context of health communication for COVID-19: utilitarian outcomes (i.e., personal health outcomes), social outcomes (i.e., social benefits/costs), and value outcome (i.e., personal/moral values). While in the case of, e.g., a pandemic, all three factors play an important role, our work focuses on diseases that have a lesser social impact and mainly involve individual persons. Therefore, we focus only on the utilitarian outcome.

Visuals are a promising approach to improving health communication and thereby countering infodemic conditions where the public is oversaturated with information [KL20]. Noar et al. [NRB*20] show that pictorial warnings (in contrast to text-only) on cigarette packs are more likely to increase intentions to quit smoking. Pictorial warnings are more engaging when they are factually accurate, i.e., when they include graphic images of diseased or damaged anatomy, real persons, and personal testimonials [OBMC19]. Thus, the content being real and personal seems to have a positive influence on health communication. This motivates our data-driven approach of utilizing real patient data beyond photos for health communication. Visualizations need to be designed appropriate to their communicative goal (e.g., a line chart is suited to show a trend) and audiences' needs (i.e., taking into account the audience's health literacy, visual literacy, and numeracy to include appropriate labels, descriptions, and visual aids) [GRC17]. However, visual communication is a challenging endeavor as seemingly minor design choices in the presentation of information can have important effects on risk perception and decision-making [MHTD23].

2.3. Visual Communication and Storytelling in Medicine

Garrison et al. [GMPB23] summarize current approaches in narrative medical visualization stating that there is still a large gap between research and practice. Meuschke et al. [MGS*22] discuss a seven-stage template for the structure of narrative medical visualizations for diseases derived from professional health web blogs. Other data-driven medical stories are structured based on concepts from theater and media, i.e., Freytag's Pyramid [KSM*22] and Campbell's Hero's Journey [MWS*23]. Budich et al. [BGPM23] focus on the design of data-driven characters derived from cohort data. So et al. [SBV*21] incorporated storytelling as a persuasive element in an interactive visualization about various medical conditions, highlighting its effectiveness in influencing participant's opinions within a user study. Practitioners employ comics to improve patient education by increasing patient comprehension and lowering periprocedural anxiety [BGH*19].

3. Cooperation With Clinical Partners

Working closely with domain experts is essential to ensure the accuracy and relevance of the medical content. We have worked with clinicians in cardiology, neurology, radiology, and epidemiology with many years of practical experience. No compensation was involved. The clinicians' main motivations are:

Prevention of common conditions. The departments of neurology and cardiology of our local university hospital have a lot of patients who suffer from the consequences of untreated hypertension. While hypertension can easily be regulated by behavioral change, e.g., a change towards a healthier lifestyle or by medication, it is often not taken seriously by patients. Therefore, physicians are interested in effectively communicating the risks posed by untreated hypertension to the local population and we cooperated to develop a narrative about how hypertension can lead to dementia [MWS*23].

Patient Education to improve patients' understanding of diseases and possible treatment methods including their risks. We cooperated with the clinics of neurology and radiology of our local university hospital to investigate how storytelling can be used to educate patients about tumors and aneurysms [MML*23]. The department of radiology is interested in developing more narratives that focus on treatment options.

Research in the medical domain requires participants. One physician explained that they usually meet patients in the late stages of certain diseases where symptoms are prominent, leading to patients visiting the hospital. To extensively research these diseases, also patients with earlier stages are interesting to examine. Additionally, chances are better when patients start the treatment while the disease is still in its early stages. By communicating symptoms of early stages of diseases as well as contact points for patients, the physicians hope to reach more patients with early stages of the disease. This was one main motivation for the narrative about hypertension [MWS*23]. Another example is epidemiological studies where a large number of participants over a long period of time is needed. Epidemiological researchers are interested in narratives that convey the importance and potential findings of these studies to their target group, hoping to motivate more persons to participate. We worked with the epidemiologists conducting the Study of Health in

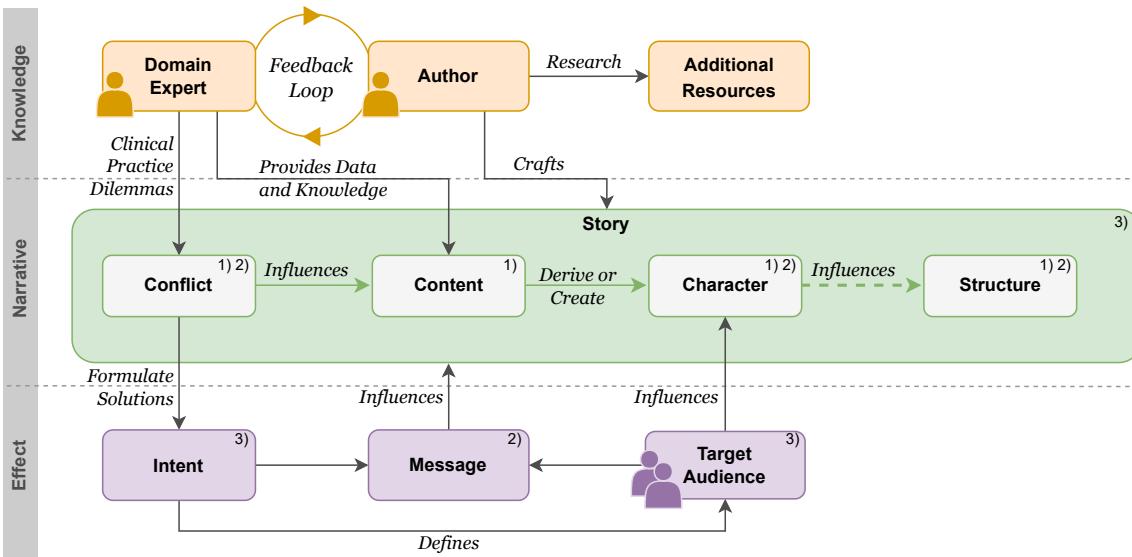


Figure 1: Narrative medical visualization design process based on the theoretical foundations of (1) Brent Dykes [Dyk19], (2) Fog et al. [FBMB10], and (3) Bach et al. [BSB*18]. Dashed lines depict optional dependencies.

Pomerania (SHIP) to determine how to communicate study data at the individual participant level [BGPBM23].

Commercial interests particularly play a role in private institutions, e.g., we cooperated with the *Herzzentrum Leipzig*, which is a private hospital specialized in heart diseases to create a narrative about the placement of an artificial heart valve (TAVI procedure) [KSM*22]. They are interested in showcasing their specialization, with certain diseases or treatment methods for prestigious reasons or to advertise the institution to potential patients. One of our cooperation partners was, therefore, interested in exhibiting narrative medical visualizations in their foyer.

With the exception of the last aspect, the interest of our clinical partners in narrative medical visualization is motivated by *Clinical Practice Dilemmas* for which it is seen as a potential solution.

4. Design Process for data-driven Medical Stories

We divide the design process into three stages: (1) the *knowledge* stage where the topic is defined, (2) the creation of the *narrative*, and (3) the *effect* the story should have, see Figure 1. The stages do not follow a strictly linear order and multiple stages might be active simultaneously. We have chosen these stages so that they can be related to the concepts of health communication shown in Figure 2, where the *effect* aligns with the *message content* and the *narrative* aligns with the *message execution*. Based on the clinicians' motivations described in Section 3, we added *message motivation* as a component corresponding to the *knowledge* stage.

4.1. Knowledge Stage: Why to Communicate

A narrative is usually motivated by *clinical practice dilemmas* (see Section 3), motivating *why* a topic needs communication.

Domain Expert. The domain expert provides data and domain knowledge. The type of data can vary, from tabular data, e.g., from a patient cohort, to imaging data from individual patients. If the domain expert is a practicing physician, they can also offer insights on how to communicate medical topics to lay audiences based on their experiences with patient consultations. Throughout the design process, the domain expert is consulted repeatedly to ensure that the narrative aligns with their expectations and experiences.

Author. The author, in our case researchers with background knowledge in medical visualization, generate appropriate visualizations to highlight important insights from the data. Based on the narrative's *Intent*, the goal is not to analyze data and find new insights, but to present data that demonstrate the medical consensus. In Section 2.1 we showed that there are several roles in the creation process of a narrative, where multiple roles can be played by one person. In small teams, the author combines all of the roles while some domain knowledge is provided by the domain expert.

External Resources. The materials provided by the domain experts can be enhanced with additional resources, e.g., the author can consult scientific literature or web sources. Adequate web sources might be the websites of professional institutions such as the World Health Organization, the National Health Service, or hospitals.

4.2. Narrative Stage: How to Communicate

During the narrative stage, many design decisions have to be made that can be linked to health message design. As depicted in Figure 2, *message execution* in health message design describes which stylistic features are used for presenting the message content without altering it, thereby exploring *how* to communicate with the audience. Due to the nature of narrative visualization, *narratives* and *visuals* are both frequently used while the *emotional appeal* is rarely considered in scientific literature.

We use Bent Dyke's data story ingredients to investigate how a narrative is built: *Conflict*, *Content*, *Characters*, and *Structure*.

Conflict. The conflict is derived from *clinical practice problems*. In most prior works the *clinical practice problem* is projected on an individual level, i.e., instead of showing statistics that hypertension can lead to dementia, show a concrete individual that develops dementia due to hypertension. That individual can act as a character in the narrative.

Content. Derived from the initial conflict, the author has to decide which data and general information is essential for the story to depict the conflict. The content should be selected based on how to best design a certain message, as described in Section 4.3.

Character. A story can have one or more characters, furthermore, there are also different types of characters for stories, such as protagonists, side characters, and antagonists [MWS*23]. Characters can be derived from, e.g., cohort data ensuring both, realism and patient anonymity [BGPM23]. A character does not need to be a person, it can also be a data point or an object. In our experience, having a patient character as a protagonist is well received by the audience as they can act as a relatable personification for the conflict.

Structure. When all the other ingredients are decided on, they need to be structured for presentation. While there is a range of different structures to pick from as described in Section 2.1, some structures, e.g., Campbell's Hero's Journey are influenced by the characters. However, we are not aware of any guidelines that might help in choosing a particular story structure, so this is currently a design choice based on the author's preferences.

4.3. Effect Stage: What to Communicate

This stage focuses on the intended effect of the narrative on the audience. The effect is closely linked to the message content (see Figure 2) as it describes what message is conveyed to the audience.

Intent. The narrative intent is defined as a solution to the *clinical practice dilemma*. For example, if the dilemma is defined as "Many patients do not take hypertension seriously, in turn, their organs are damaged over time, leading to diseases like dementia." then the intent would be to educate about the risks of hypertension to motivate behavioral change towards an adequate treatment thereby preventing organ damage. The intent of a narrative has the potential to be a significant field of tension between being neutral and objective (as often inspired by journalists and data visualization professionals) and persuading the audience towards health-improving behavioral changes (which is the goal of health communication, public health, and our clinical cooperation partners). We think that in terms of narrative medical visualization, formulating the intent as a learning objective, as proposed by Lee-Robbins and Adar [LRA23], is the most promising approach.

Message. The key message of the story is derived from the *intent* and shapes the content of the story. It summarizes *what* the author wants to tell the audience. The *message content* consists of two aspects: *outcome beliefs* and *efficiency beliefs*, see Figure 2.

To address *outcome beliefs* in health communication, commonly the persuasion technique *arguments-from-consequences* is used [O'K13], i.e., a behavioral change is motivated by showing

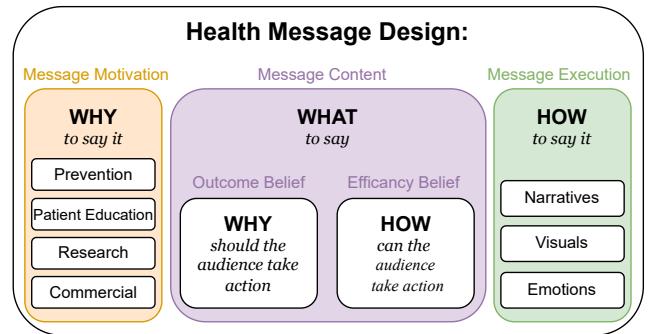


Figure 2: Aspects of health message design from Nan et al. [NIYM22] expanded by message motivation from Section 3.

potential consequences. In cooperation with our clinical partners, we also followed this technique. Depending on the intent of the narrative, we either show negative consequences from not taking action (e.g., unhealthy lifestyle can lead to disease) or positive outcomes (e.g., treatment can improve a condition), or even both within the same narrative. These strategies are called preventive focus (showing negative outcomes due to not taking action) and promotion focus (showing positive outcomes due to taking action) in social psychology [NIYM22]. Which is more effective, differs for each individual, thus there is no clear recommendation towards one or the other. Similar effects can be seen for the time frame [NIYM22]. A message can be short-term-focused (consequences that apply in the near future, i.e., results of surgery) or long-term-focused (consequences that apply in the distant future, i.e., organ damage due to years of untreated hypertension). In our previous works, we mostly focused on long-term consequences as they are often more severe and fit the clinical practice dilemmas.

Efficiency believes (the belief that an individual or community can achieve the desired outcome) has not been investigated in the context of narrative medical visualization so far. However, especially for medical topics that aim at promoting healthier lifestyles, efficiency is an important aspect of making a message more effective. While we did tell the audience how to, i.e., take preventive measures for certain diseases, this was done by simply listing options for positive lifestyle changes. Following other recommendations for boosting self-efficacy beliefs, such as goal setting or role modeling, could increase message effectiveness [NIYM22].

Target Audience. Based on the *intent*, the *target audience* can be defined, e.g., who is causing or who can solve the *clinical practice dilemmas*. The impact of a story also heavily depends on how much the audience cares about the topic. The *congruency rule* or *matching effect* describe that *arguments-from-consequence* is most effective when outcomes perceived as desirable by the audience are emphasized [O'K13]. Thus, a good understanding of the target audience is crucial to designing an effective message that achieves the narrative intent. Again, discussions with the domain experts proved useful to gain a deeper understanding of the target audience, e.g., by identifying typical questions and concerns patients express when consulting physicians.

5. Reflections and Future Research Directions

Narrative medical visualization is a research area from the computer science domain but aligns closely with efforts from health communication. We provided a design pipeline and clinical application cases to guide the design of future narrative medical visualizations. We showed that many aspects of health communication are already met in our design process, while others could be incorporated in the design of future stories to enhance their effectiveness. In particular, we want to highlight the following aspects:

Efficiency Believes. The effectiveness of a health message also depends on whether the audience believes that the desired outcomes can be achieved. However, we are not aware of any publications that consider this aspect for narrative medical visualization. Being part of the computer science domain, we see great possibilities for investigating strategies to enhance efficiency through technical solutions, such as allowing users to compare themselves with information from cohort data.

Emotional Appeal. Emotional appeal is an important factor in health message design, but current research on narrative medical visualization neglects it. While Mittenentzwei et al. [MWS*23] asked participants to rate their emotions after seeing a narrative on a scale ranging from extremely positive to extremely negative, the results were not connected to the persuasive effect of the narrative. Future advancements should investigate emotional appearance and potential relationships with emotional story arcs [RMK*16].

Engaging Narratives. A good narrative follows a question-and-answer pattern, surprising the audience with unexpected answers [MH21]. Current work in narrative medical visualization focuses on organizing information in a logical and easy-to-follow way but neglects the entertainment factor popular narratives possess. Therefore, future narratives should aim to generate more engaging experiences.

Utilizing principles from health communication allows authors to follow a structured approach when designing medical narrative visualizations, potentially leading to more effective narratives. However, experiences from other directions, such as entertainment media and journalism can further improve our narratives as an intriguing narrative aids in keeping the audience interested.

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