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**A Design Language for Prototyping and Storyboarding Data-Driven Stories**

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Mémoire présenté en vue de l'obtention du diplôme de *Maîtrise ès sciences appliquées*  
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**A Design Language for Prototyping and Storyboarding Data-Driven Stories**

présenté par **Morteza ASGARI**

en vue de l'obtention du diplôme de *Maîtrise ès sciences appliquées*

a été dûment accepté par le jury d'examen constitué de :

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**Philippe DOYON-POULIN**, membre

## DEDICATION

*To my mother,  
who sacrificed a lot for me*

*To my father,  
who believed in my abilities,*

*To my supervisor,  
who taught me to be patient. . .*

## ACKNOWLEDGEMENTS

I would like to express my heartfelt gratitude to my mother, whose unwavering support and sacrifices have been the cornerstone of my journey. Her love and encouragement have been my guiding light, motivating me to persevere and achieve my goals. I am also deeply thankful to my father, whose belief in my abilities and constant reminders to stay determined have been invaluable. His wise counsel and encouragement have been a source of inspiration throughout my academic pursuits.

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This journey was full of learning opportunities, and I am grateful for each one that has shaped me into the person I am today...

## RÉSUMÉ

Les histoires basées sur les données (DDS) sont des formes numériques de narration qui organisent les données et les visualisations pour communiquer un récit d'informations à un public. Ils ont connu une croissance rapide au cours des dernières décennies. En conséquence, une grande diversité apparaît dans les formes de DDS publiées. Les structures récentes des DDS sont plus complexes, respectant leur disposition, leur composition, leurs caractéristiques et leurs parties internes. Dans les recherches universitaires actuelles, ni les techniques de narration ni les taxonomies ne suggèrent des mécanismes visuels permettant de distinguer les différentes mises en page, compositions et arrangements. L'absence d'une solution visuelle expressive intégrant différentes parties de DDS sous une seule structure empêche les auteurs d'essayer des voies de conception plus alternatives dans le processus de conception de l'histoire. Dans ce mémoire, nous unifions toutes les parties constructives du DDS pour définir la structure narrative comme une représentation visuellement structurée du récit DDS, qui est formée et conçue par leurs éléments constructifs. Cette solution propose un langage de conception composé d'un ensemble de règles de conception qui intègrent les éléments visuels pour représenter la structure narrative du DDS. Notre évaluation du processus d'audit sur 100 exemples DDS confirme que le langage de conception est complet, expressif et polyvalent. De plus, nous avons développé DataStoryDesign, un outil qui intègre cette solution visuelle pour le prototypage et le storyboard DDS pour une équipe d'auteurs DDS. Le résultat préliminaire de l'évaluation exploratoire indique qu'une telle solution est efficace pour le prototypage et le storyboarding DDS. De plus, nos résultats confirment que le langage proposé améliore la communication visuelle entre différents acteurs impliqués dans le flux de production DDS.

## ABSTRACT

Data-driven Stories (DDS) are digital forms of storytelling that arrange data and visualizations to communicate a narrative of information to an audience. They have been growing fast over the past decades. As a result, a great degree of versatility appears in the forms of published DDS. The recent structures of DDS are more complex, respecting their arrangement, composition, features, and inner parts. In the current academic research, neither storytelling techniques nor any taxonomies suggest visual mechanisms to distinguish between different layouts, compositions, and arrangements. The lack of an expressive visual solution that integrates different parts of DDS under one structure abstains the authors from trying more alternative design paths in the story design process. In this proposed work, we unify all the constructing parts of DDS to define the narrative structure as a visually structured representation of the DDS narrative, which is formed and designed by their constructing elements. This solution proposes a design language consisting of a set of design rules that integrate the visual elements to represent the DDS narrative structure. Our evaluation of the audit process out of 100 DDS examples confirms that the design language is comprehensive, expressive, and versatile. Additionally, we developed DataStoryDesign, a tool that incorporates this visual solution to facilitate prototyping and storyboarding DDS for a team of DDS authors. The preliminary result of the exploratory evaluation indicates that such a solution is effective in prototyping and storyboarding DDS. In addition, our findings confirmed that the existence of our design language improves the visual communication between different personas in the DDS production workflow.

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**LIST OF SYMBOLS AND ACRONYMS**

DDS	Data-Driven Stories
UX	User Experience
WYSIWYG	What You See Is What You Get

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## CHAPTER 1 INTRODUCTION

### 1.1 Background

The rise of the internet in recent years has made journalism evolve into different forms. New ways of data communication have emerged in recent years. Among them, Data-Driven Stories (DDS), also known as narrative visualizations, have been growing fast over the past decade. DDS are digital forms of storytelling that arrange data and visualizations to communicate a narrative of information to an audience. As the demand for consuming online news increases, the publication of online stories is experiencing a considerable surge [8, 9]. Journalists are pushing the boundaries of DDS production by combining storytelling techniques with various ways of visualizing data. Consequently, a great degree of versatility appears in the forms of published DDS. Journalists and DDS authors<sup>1</sup> have been trying more complex data to infuse their DDS with compelling data analysis. Working with large datasets adds to the complexity of the structure of modern DDS. In addition, nowadays, DDS is starting to be used in fields other than journalism. Therefore, the implications of DDS vary depending on the fields and requirements. These new changes create the necessity for a deeper understanding of DDS, their composition, arrangement, and inner parts. As a result, the research community investigates the identification and classification of the different aspects of DDS, including its structure.

While Seyser and Zeiller use the term narrative structure to describe the path structure of DDS, another study on narrative structure reveals that this terminology encompasses more components than that [10]. The concept of narrative structure is a multi-faceted topic. Therefore, DDS studies usually analyze different aspects of DDS narrative structure, like arrangement, composition, and features separately (e.g., layouts, path structures, components, transitions). In this proposed research, we unify different methods of visualizing, representing, prototyping, storyboarding, and structuring the DDS narrative suggested by previous studies and industry under one umbrella term called DDS narrative structure. We define *DDS narrative structure* as a visually structured representation of the DDS narrative, which is formed by their constructing elements. In other words, the DDS narrative structure points to visual-related aspects of the DDS narrative to represent a single integrated structure for each DDS. Our goal is to identify these constructing elements to achieve such a representation.

---

<sup>1</sup>The term "DDS authors" refers to all different personas involved in DDS production.

Some studies propose comprehensive taxonomies that target various aspects of DDS [4, 9, 11–17]. These taxonomies classify and describe all visual attributes related to the DDS narrative structure, mainly in descriptive dimensions. They recognize overall patterns and strategies used in the stories. DDS studies sometimes call these taxonomies by other names like patterns, design spaces, and surveys. Among these taxonomies, they primarily focus on storytelling techniques. Storytelling in the context of data journalism goes beyond shapes, forms, and unarticulated narratives. Storytelling techniques are supposed to evoke emotions and enhance communication on the reader’s side [18, 19]. Therefore, in the modern era of journalism, famous news publishers (media outlets) use specific trends, patterns, and storytelling techniques more frequently [11, 15, 19–21]. Designing DDS based on storytelling approaches and limitations encourages creators to think critically about the context and implications of the data, specifically when the data are large and multidimensional [22]. Storytelling techniques describe the narrative structure of DDS by recognizing specific arrangements and composition of data in the story (e.g., emphasizing specific narrative skills and prioritizing information based on certain storytelling patterns).

The studies on DDS narrative structure also cultivate the development of DDS authoring tools<sup>2</sup> and its associated collaborative processes. The domain of this definition encompasses a wide range of applications: visualization platforms, data analysis, visualization adjustments, and publishing DDS. Among these categories, only the tools that publish the final version of DDS implemented their models of representing DDS narrative structure to a certain extent [5–7, 23–26]. Besides producing DDS, these tools contribute to the understanding and collaborative aspect of DDS workflow (e.g., storyboarding, brainstorming, prototyping).

## 1.2 Problem Statement

In journalism, DDS authors run into more complex forms of DDS in terms of arrangement, composition, and interactivity. These stories sometimes offer complex layouts intertwined with visualizations within the narrative. Techniques like transitions and animations are no longer used just to enhance visual cues for communication but as an inseparable part of the narrative. Overlapping visual elements, immersive DDS articles, and uncovering hidden insights through interactivity are examples of the more complex forms of DDS. In these examples, many DDS parts are incorporated to make a complex narrative structure. The current DDS research and the DDS industry don’t propose a solution to incorporate visual parts of DDS as one integrated structure through the academic resources and the current authoring tools.

---

<sup>2</sup>The term "DDS authoring tools" refers to any tool that contributes to the DDS production workflow.

In current academic research, neither storytelling techniques nor taxonomies suggest visual mechanisms to distinguish between layouts, compositions, and arrangements. Although the demand for expressive visual solutions becomes more evident as the field progresses, this gap has remained inexplicable. The current visual solutions are not expressive enough to explain the complexity and versatility associated with DDS narratives. Without such a mechanism, authors usually fixate on one or very few design pathways [27,28]. The lack of a comprehensive representation of the DDS structure also appears in the current DDS authoring tools. This problem prevents them from providing a better prototyping or storyboarding system for complex DDS narratives. As a result, in DDS production, visual communication is affected by various personas. Additionally, within the existing DDS authoring tools, there is a lack of emphasis on the design process of the narrative structure. Since they do not put story design as the core strategy of their design practice, fewer personas get involved. The newsrooms and media outlets put more resources into producing complex forms of DDS [10]. Without such an apparatus, the authors don't get a chance to try more alternative paths. This problem also becomes a gap in DDS authoring tools since they don't put narrative design in the precedent of their workflow. These tools contribute to DDS production by facilitating multimedia integration. They facilitate the publishing process for less technical users by providing a range of patterns and templates in predefined settings. Professional journalists and the news industry encounter more situations where the data and story implications require a comprehensive solution, yet current models don't hold the newsroom standards.

### 1.3 Motivation and Contributions

All aspects of DDS make it challenging to propose an ultimate expression language for the DDS narrative structure. The primary motivation for this proposed research work is to provide a better understanding of more complex forms of DDS. The inspiration to fill this gap is finding a more expressive narrative structure in the story design process. Another motivation is to inform authoring tools as a medium that incorporates expressive narrative solutions for DDS. In this regard, our work follows a dual approach of prototyping and storyboarding standpoint, specifically as a practice intertwined with story design, storyboarding, and brainstorming. We got inspired by storyboarding practice, which has a simple yet effective visual communicative language [29]. This proposed research aims to unify all the constructing parts of the DDS narrative structure under one shared interpretation and model.

A design language through a prototyping and storyboarding system may gather all personas around the story design process, letting them elevate the idea generation phase. In addition, it lets them try more alternative paths of their story with a close to identical visual commu-

nication ground. In addition, this work informs the future development of DDS authoring tools by imposing design rules integrated within a prototyping and storyboarding system in their workflow. We evaluated the effectiveness of this language both as an ultimate visual solution for describing DDS and as a prototyping and storyboarding device in an authoring process. Furthermore, this proposed research validates whether this language improves the DDS production and communication process.

We reviewed resources and academic works on DDS narrative structure and collaborative practices in journalism. To propose such a visual solution and a prototyping and storyboarding system for it, we engaged in a series of brainstorming sessions with Le Devoir newsroom's DDS authors and explored different DDS examples and authoring tools. To evaluate the design language's expressiveness and comprehensiveness, we conducted an audit on 100 DDS examples from notable DDS media outlets. We then developed DataStoryDesign to evaluate the prototyping and storyboarding aspects of the design language. Finally, we evaluated the effectiveness of the language as a prototyping and storyboarding device incorporated into an authoring workflow through DataStoryDesign by a team of DDS authors from Le Devoir. Furthermore, through the evaluation process, this proposed research investigated whether this visual solution helps the DDS production and communication process since it offers understandable design elements and visual cues. The proposed work has the following contributions:

1. Proposing a visual solution for DDS narrative structure, called the design language
2. Evaluating the effectiveness of the design language in Step 1 by showing its versatility, comprehensiveness, and expressiveness through the audit of 100 curated DDS examples from notable journals
3. Evaluating the effectiveness of the design language proposed in Step 1 as a prototyping and storyboarding device in an authoring system through a team of DDS authors at the Le Devoir newsroom
4. Validating whether the design language proposed in Step 1 improves the visual communication between different personas in the DDS production workflow or not

## CHAPTER 2 RELATED STUDY

In this Chapter, we discuss different aspects of DDS that directly and indirectly target the topic of the DDS narrative. This Chapter breaks into two main sections: DDS Narrative Structure (Section 2.1) and Collaborative Process for Producing DDS (Section 2.2). The first section goes directly through all academic resources to convey this concept. The second part of this Chapter explains how the collaborative processes, practices, and workflows affect the DDS narrative.

### 2.1 DDS Narrative Structure

As a digital product of journalism, DDS combines text and data portrayed as visualization in a narrative format [8, 9, 30]. Today, DDS is a popular way of communicating information by online media outlets [8, 15, 31]. Recently, the longer formats of digital journalism, also called long-form journalism, are increasingly used by online media as a powerful way of storytelling [30]. Among them, a specific form of long-form journalism is called scrollytelling, a combination of storytelling and scrolling [10]. However, other studies define scrollytelling as a type of DDS that unfolds content exclusively through scrolling [11, 32]. A classification by Godulla and Wolf suggests that scrollytelling is one of the three types of long-form journalism, web documentation, and selective multimedia story. They also list scrolling features such as selectivity, interactivity, linking, multimedia, and participation of the audience [3]. Seyser and Zeiller mention scrollytelling as a text-centric journalism that usually starts with full-screen media and scrolls vertically [10]. According to them, scrollytelling is a suitable option for creating more complex narratives when it is combined with a lot of multimedia content, larger data sets, and highly interactive infographics. While they argue this makes multi-faceted scrollytelling more costly to produce, it is widely being used by notable media outlets like The New York Times [10]. Figure 2.1 shows different examples of DDS. We took these examples from notable news websites.

The concept of narrative at the heart of DDS has been the subject of research for many years. Some sources define narrative as a representation of an event or a series of events [33, 34]. Tong et al. indicate that the narrative deals with how the authors tell stories [35]. Outa et al. define a data narrative as a constructed composition of information that delivers findings with data, usually through visual means, to improve communication by the target audience [36]. Hullman et al. clarify that story creation is a consecutive process of defining the context, selecting the information modality, and choosing a structure to effectively deliver

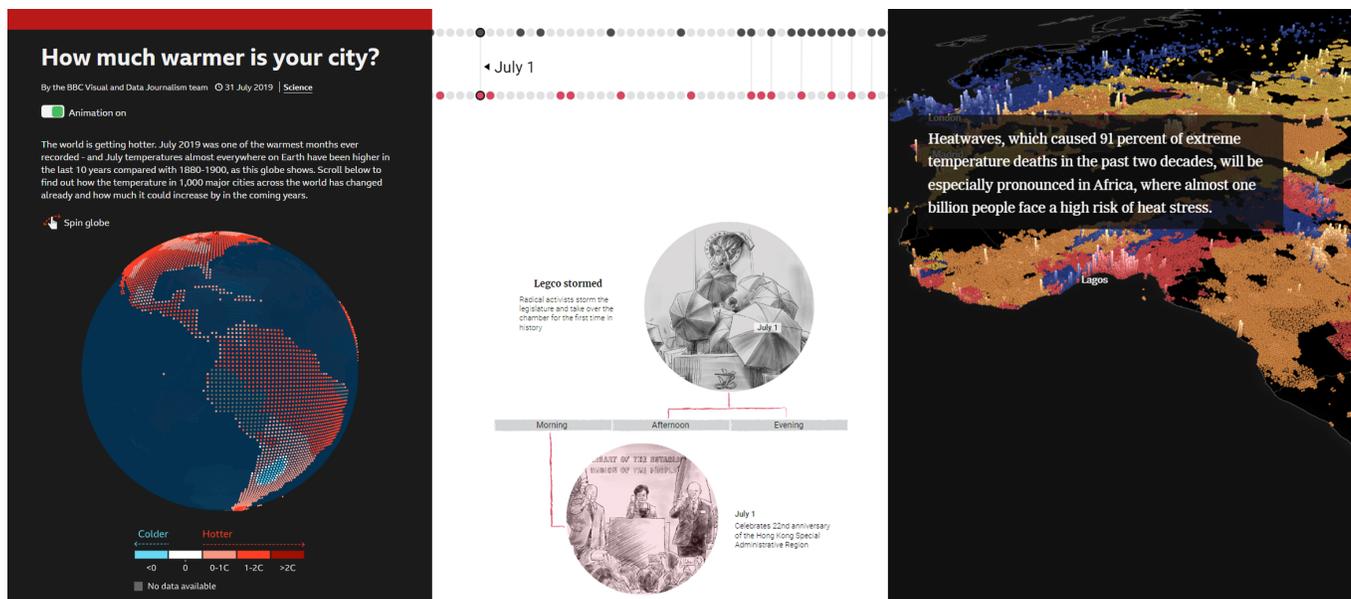


Figure 2.1 DDS examples: From left to right, taken from [bbc.co.uk](http://bbc.co.uk), [scmp.com](http://scmp.com) and [nytimes.com](http://nytimes.com)

the desired narrative [2]. Plowman and Luckin consider the creation of a narrative of a story as an active process of meaning-making, also called sense-making [37]. Eccles et al. argue that although both terms of narrative and story seem synonymous, the narrative refers to the macro-structure of a document while a story points to both structure and content [38]. Lee and Riche describe that DDS may not have a narrative structure, but it certainly has components to form a story. They also emphasize the necessity of the presence of story components, including structure, elements, and concepts, as the telling part of storytelling despite the lack of a predefined temporal or narrative structure [39]. On the contrary, Seyser and Zeiller tie the success of DDS in online journalism to their narrative structures, media choice, and compositions [10]. The main problem regarding the term narrative comes from the ambiguity of its domain. In this proposed work, we argue that DDS have a structure even in their simplest non-interactive forms. In this proposed work, we identify these structures, their differences, and their limitations.

### 2.1.1 Core Dichotomy of DDS Structure

Understanding and formulating storytelling has been the subject of interest since ancient times [9]. Likewise, since DDS has emerged, studies have endeavored to comprehend and structure the fundamental components of DDS. On a basic level, the DDS narrative is a macro-structure that forms a global coherence of the story's content [37]. Multiple studies explain that the term narrative refers to the macro-level structure of the document, while the

story refers to both the structure and the content of the document [35, 37, 38]. Plowman and Luckin characterize the terms macro-narrative and micro-narrative, respectively, as the global structure and the lower-level task units [37]. On a different spectrum, stories are dissected into conceptually separated integral episodes forming constituent story plots [2, 40]. Hullman et al. identify these plots as macro-structure and episodes as micro-structure triggered by events [2]. Several studies talk about the existence of a macro-framed and a micro-framed structure in the story [2, 37, 40]. Zhao et al. introduce encapsulation in data comics where a structure is divisible into smaller structures on multiple levels [41]. The micro level is also encapsulated with smaller segments through layouting or partitioning. Furthermore, the final content and graphs are also divisible into parallel or overlaying compositions, as this text calls it, the *inner-narrative structure*. Table 2.1 compare the proposed terminologies between the cited studies.

[2]	[37]	[40]
macro-structure	macro-narrative	plot
micro-structure	micro-narrative	episode

Table 2.1 Correspondence table between terminologies

Some studies propose framing the macro-structure of DDS based on the author’s participation in the audience’s analysis. Authors create DDS on the spectrum of two directions called Author-driven and Reader-driven. Author-driven stories are often portrayed as explanatory visualizations. On the other hand, reader-driven stories are the ones that have more exploratory visualizations. Stories nowadays may use a mixed approach consisting of both exploratory and explanatory visualizations since they use more compounded structures [9, 28]. Segel and Heer count three main criteria for comparing author-driven versus reader-driven stories: ordering, interactivity, and messaging. Ordering refers to the different paths that the viewers traverse in the story. In some cases, authors heavily prescribe ordering, limiting the user’s interaction to just progressing through the story. Author-driven DDS usually has a linear structure with heavy messaging and less interactivity than reader-driven DDS. They mention some hybrid categories where the story’s ordering uses author- and reader-driven features. Structures like martini glass with predominant author-driven features, drill-down stories with a primary reader-driven and interactive slideshow with a more balanced approach [9].

### 2.1.2 DDS Components

Every DDS scenario spreads the story through a series of scenes or shots. Kim refers to these frames as a snapshot of an individual visualization of some of the data. The study suggests that when there is a significant change, the number of scenes increases [42]. Tang et al. define the term narrative state in a clip as an informationally distinct scene for presenting information in different formats [43]. Hullman et al. adopt the same terminology for DDS [2]. Segel and Heer discuss that some structures, such as interactive slideshows, use single-frame interactivity without directing the audience to a new visual scene [9]. The continuity of scenes or narrative states makes up the story. The number of visual elements may vary in a single scene. These elements change through a stream of consecutive states. Marcelino et al. name this sequence of segments a visual storyline [44]. In a single visual scene, there is usually more than one element, each of which may have a separate storyline. The connection between these visual elements and their previous states depends on the actual narrative voice of the story. Multiple levels of abstraction apply to visual storylines. On the highest level of abstraction, the authors consider the whole elements within a single scene as one unit. This distinction creates a single storyline for the whole story between different scenes. Similarly, according to Brehmer et al., a DDS timeline represents the time axis or the sequence of events or intervals data based on the chronological order of narrative elements in time [17]. They describe a more detailed timeline as an indicator of the story events in chronological time, the duration of those events, and their possible overlaps [17]. In this proposed research, we distinguish between two concepts of timelines and storylines. Timeline points to the actual timing of the narrative events in the story, while storyline defines the scene structure of DDS, e.g., the hundred-year-old interval between two events in the story represents its timeline, while scenes with visual elements plot these changes through multiple states representing the storyline.

DDS encompasses a collection of multimedia content. Researchers in the field of long-form journalism refer to the incorporation of multimedia features as multimodality [30]. Several studies describe different DDS formats with multimedia features [3,10,30]. Some DDS articles show up to seven different types of multimedia content, especially in recent years with the breakthrough of the internet [10]. Seyser and Zeiller highlight that in most cases, scrollytelling articles start with a full-screen photograph or video. They emphasize the role of text in image-centric scrollytelling in addition to other content such as photos, graphics, and animations [10]. Zhao and Elmqvist name audio, music, image, video, graph, anim, and text as the media components of DDS. They also name another group of components called data components, e.g., map, textvis, etc. [45].

### 2.1.3 DDS Path Structures

There are different ways of arranging the content of DDS. These arrangements result in different pathways for the audience to traverse the structure of DDS. Segel and Heer call this concept ordering by proposing three types: linear, user-directed, and random access. They distinguish between the different ordering types by examining how much authors have prescribed the story pathway [9]. The linear structure also has been proposed by several other studies as the most direct approach where the author dictates the direction of story exploration [3, 10, 11, 32, 35, 46]. Therefore, authors communicate their messages in a linear structure to deliver specific data analysis. According to Some studies, scrollytelling is a form of author-driven DDS that uses linear path structure [10, 11, 32]. In addition, some of them [11, 32] also indicate that in a scrollytelling DDS, the progression is strictly enforced by scrolling [11, 32]. Weber introduces two more structures for exploratory storytelling, nonlinear and linear-nonlinear, where the story gives the audience a certain level of freedom to explore multiple paths. Exploratory visualization’s path structure, in particular, depends on the narrative of visual elements on the scene, sometimes spread through multiple layers of stacking [46]. The narrative of events in the story primarily determines the path structure of the story. These events direct the readers to a new scene or the same scene with different visual elements. The depth of narrative structure is also defined within each scene when visual elements can produce various results each time.

In linear-nonlinear structure introduced by some studies are side branches to the story where the user can separate from or return to the original path of the story [10, 46]. Similarly, other studies propose the elastic structure with the same features for scrollytelling and long-form DDS [3, 10]. Since scrollytelling has become popular recently, long-form DDS almost have become equivalent to scrollytelling DDS. In this proposed work, we consider these two terms synonyms. Some studies propose the user-directed structure where the readers choose their entry point in a multi-path structure [9, 10]. Similar to these studies, other studies present the same concept as the threads structure [3, 10]. Although in the elastic and threads structure [3, 10], readers end up with a specific ending, while in the user-directed structure [9], this ending may be different regarding the path the reader takes. Segel and Heer define the random access structure as a pathway with no administered path by the authors [9]. Similarly, Weber proposes the nonlinear structure with a similar feature [46].

Parallel structure is ambiguous in different academic resources. Several studies define parallel structure in the context of scrollytelling, where the choice of navigation determines the story’s path. These studies also mention that the finishing point of the parallel path may merge at the end; however, the final scene of DDS may be different [3, 10]. The user-directed structure

by some studies [9, 10] potentially creates a similar parallel concept in DDS. Similarly, the threads structure by Godulla and Wolf serve the same purpose [3]. On the other hand, Tong et al. completely changed the meaning of parallel structure. They define this term as a pathway that traverses alternative paths simultaneously observable [35]. In order to support the parallel structure by Tong et al., a scene should break into two concurrent visible parts. Therefore, this parallel definition [35] separates itself from the other studies [3, 9, 10].

Various studies proposed more complex structures, including branched out, concentric, and chapters. The branched out structure is similar to a tree where each path has multiple new paths in different scenarios. The Concentric structure indicates that a centric point is necessary for beginning and finishing the story. The chapters structure shows that with one specific starting point, different chapters of the story are accessible through other chapters with no hierarchical order [3, 10]. In addition, through an experiment, Norambuena et al. found out that authors of narrative maps usually use three types of path structure in their stories: lists (linear), trees, and acyclic (transitive closure) directed-graphs, all inspired by the graph structure. They simplify them by two, eliminating the lists [47]. One problem regarding the current classifications is the lack of a procedure or guidelines to visually connect the macro level to the inner parts of DDS on the micro level. In other words, these studies don't distinguish what is a visual scene and how elements in the scene combine to create a different path in the story. Table 2.2 shows the correspondence of different path structures in the various studies.

[3] [10](scrollytelling)	[9]	[35]	[46] [10](storytelling)	[11] (scrollytelling)
linear	linear	linear	linear	linear
elastic	user-directed	user-directed	linear-nonlinear	
parallel	user-directed	user-directed	linear-nonlinear	
threads	user-directed	user-directed	linear-nonlinear	
branched out	user-directed	user-directed	linear-nonlinear	
concentric	user-directed	user-directed	linear-nonlinear	
in chapters	user-directed	user-directed	linear-nonlinear	
	random access	random access	nonlinear	
all	all	parallel (simultaneous)	all	all

Table 2.2 Correspondence table between various path structures

#### 2.1.4 Visual Parallelism in DDS

The concept of parallelism is adopted from linguistics and literature by Corbett and Connors is a rhetorical tool for expressing a series of similar or equivalent concepts [48]. Some studies adopt the same concept for visual analytics as a technique to show the equal importance of two concepts, linguistic statements, or visual features side by side [2, 48, 49]. Parallelism, on

the macro level, appears in the path structure of DDS. If stories break further, parallelism also appears on the micro level of the narrative structure in layouting and transitioning. Furthermore, on a deeper level of inner-narrative, parallelism appears in the story’s narrative.

Since parallelism comes in different levels, it depends on the number of elements, the number of scenes, and the simultaneousness of the occurrences. Some studies [3, 10] interpret the term parallelism differently compared to Tong et al. [35]. These studies occupy parallelism on the path structure level of DDS as parallel structure [3, 10]. Different alternative paths are descendants from the starting node of the story. On the other hand, Tong et al. use parallelism to express concurrent narratives. Tong et al. suggest that regardless of the path structure of the story, each part may have separate parallel narration within the main narrative [35]. Some examples are multiple drawn lines on a single chart, multi-tab interactive visualizations, etc. Hullman et al. point to transition parallelism as a syntactic structure repeated in a text to relate two narrative statements in one DDS scene [2]. In other words, visual elements occur on the DDS scene, primarily by order against their precedent and parallel elements. Therefore, in most cases, timelines of DDS, especially on author-driven forms, are order-dependent rather than time-based. Another form of parallelism, parallel layout, comes from data comics [4]. This form of parallelism, called layout parallelism, exemplifies aligned partitioned content when two visual elements appear with synchronized timing. Since different variations of parallelism exist, none of these studies attempt to connect these variations under one unified structure. Figure 2.2 shows different variations of parallelism: parallel narrative, parallel transition, parallel path structure, and parallel layout.

### 2.1.5 Transition and Staging

The change between the narrative visualization states is called a transition. The content of transitions is data-driven arguments, animated content without visualization, and visualization content [43]. Hullman et al. consider unique single static visualizations as a separate state although they get processed sequentially [2]. Heer and Robertson describe the transitions between graphics modeling through state changes [50].

To explain visual elements transitioning, it is easier to showcase the initial and final stages with an arrow connection to point out the change direction. This demonstration method is a simpler variation of a directed network graph with two nodes where visualization scenes are the nodes. All transitions are explainable, at least with their initial and final states. Hullman et al. propose a graph-based approach to demonstrate transition in narrative visualizations in which the visualization states represent nodes connected by an arrow. This arrow connects the initial and final stage of the transition [2].

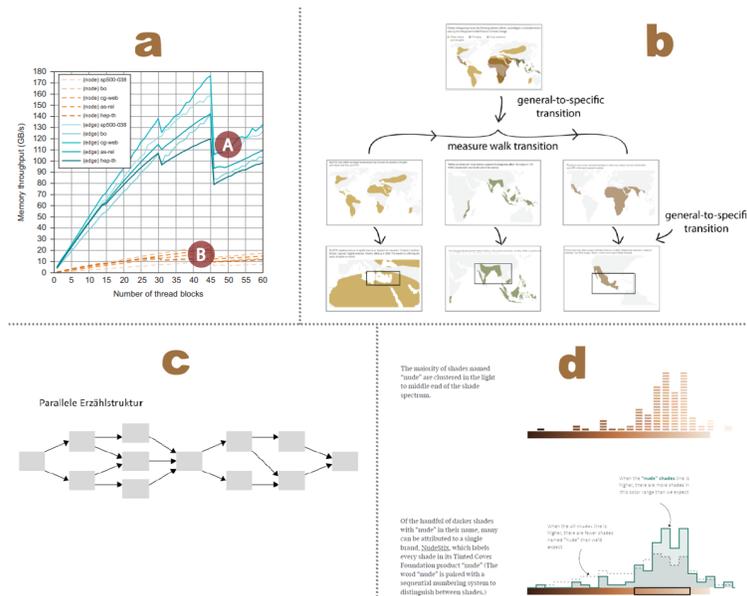


Figure 2.2 Parallelism all variations: (a) Parallelism as parallel narrative by Jia et al. (one element, one scene, simultaneous) [1], (b) Parallelism as parallel transition by Hullman et al. (one element, one scene, non-simultaneous) [2], (c) Parallelism as parallel path structure by Godulla and Wolf (multiple element, multiple scenes, non-simultaneous) [3], (d) Parallelism as parallel layout (multiple element, one scene, simultaneous) (example taken from pudding.cool)

The complexity of the transition is directly related to the number of key points of the transition. Each complex transition is divisible into a sequence of simpler sub-transitions. This concept is called staging as a design consideration for complex transitions [50, 51]. Heer and Robertson suggest staging enables authors to observe multiple changes at once [50]. Kim et al. introduce minimum staging as using only the first and last stages of transitions. They argue minimum staging may not be the optimal option as it may prevent the target concept from being adequately conveyed. They propose appropriate pauses to be used as extra stages. The goal should not be enforcing design guidelines on transitions while giving designers the freedom to express [51]. Several studies propose taxonomies for transition in data graphics and DDS. These studies diagnose different types of transitions or, in many cases, parallel transitions, but they lack any visual guidelines to demonstrate this versatility in a narrative design [2, 50, 52].

### 2.1.6 Graph-based Representation

Graph-based approaches are directed network graph representations for DDS path structure. Hullman et al. apply a simpler form of graph-based visualizations with two states to demonstrate transitions [2]. More variations of graph-based visualizations with higher node densities are usable on the macro level of DDS. Some studies use them, although they do not provide any guidelines to draw such a structure [3, 46, 47]. Weber uses nodes and line connections to represent a graph visualization for the path structure of a story [46]. Godulla and Wolf use a similar demonstration using a directed-graph with arrows and rectangles as a replica for visual scenes [3]. Through an experiment, Norambuena et al. also showcase the usage of directed graph structure in presenting DDS scenes [47].

The scenes' direction and connections are the most important aspects of a path structure. In this regard, graph-based representation is an effective way to represent the path of DDS since it demonstrates all the paths within the story. With graph-based visualization, it's not necessary to bring all the details. However, graph-based structures are not helpful for the micro-scale representation of DDS. On this level, visual scenes encompass the main visual elements. Alongside the story, these elements play visual roles to advance the narrative. Since the graph-based structure is based on minimizing the details in a visual scene, the result will not adequately express many types of arrangements and motions. Graph-based structures don't effectively represent inner-narrative episodes either, since the detail increases as we divide charts and graphics to separate elements. Figure 2.3 shows the transition demonstration by Hullman et al. [2].

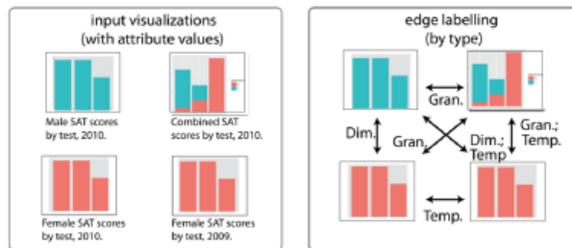


Figure 2.3 Transition demonstration by Hullman et al. [2]

### 2.1.7 Prototypical Representation

In UX (User Experience) design, prototypes are primitive depictions of final products. Similarly, prototyping in DDS aims to provide an early representation of the final story. Sketching is a formless and quick way of prototyping. Like sketching, which Weber and Rall consider as a visual communication device contributing to the thinking process, the goal of prototyping is elevating the thinking process [29]. Other studies demonstrate some notions of prototyping long-form DDS without providing any practical strategy [3, 30]. Hiippala demonstrates segmenting a page based on the content modality, called this composite as page-flow [30]. In the same direction, Van Der Nat et al. provide more detail on interactive narratives, performing experimental visual prototypes of five different DDS examples. Their visual prototypes are not based on WYSIWYG design in which the design resembles the final product. Although their representation provides a detailed flow diagram of DDS entities and audience activities [53]. Their work mainly focuses on analysis purposes rather than providing a method of representing DDS narrative structure. Godulla and Wolf illustrate prototyping with more versatility. On the micro level, they do it by reproducing the layout segmented by its elements with a minimal depiction. They specify an alphabet letter to determine the modality of the content. They sometimes incorporate using an arrow alongside their model to demonstrate the flow direction of the document. They incorporate the graph-based structure on the macro level by connecting these visual elements of the scene to other visual states. Godulla and Wolf prototyping solution support overlapped segmentation to represent the content's actual layout. Their representation serves as a skeleton of the original content with symbols depicting the media types of the story [3]. Their representation is based on WYSIWYG through a wireframe structure [54].

Although the prototypes proposed by some studies [3, 30] are good options for the story's segmentation, they still lack expressiveness in arrangements and motions. In their work, the inner elements of a whole layout are disconnected. In the case of animations and motions,

their models fail to represent the final state, the quality of change, and the dynamic with other elements. They also share the same problem with graph-based visualizations for representing inner-narrative elements and arrangement [3,30]. Figure 2.4 presents the prototyping representation by Godulla and Wolf [3].

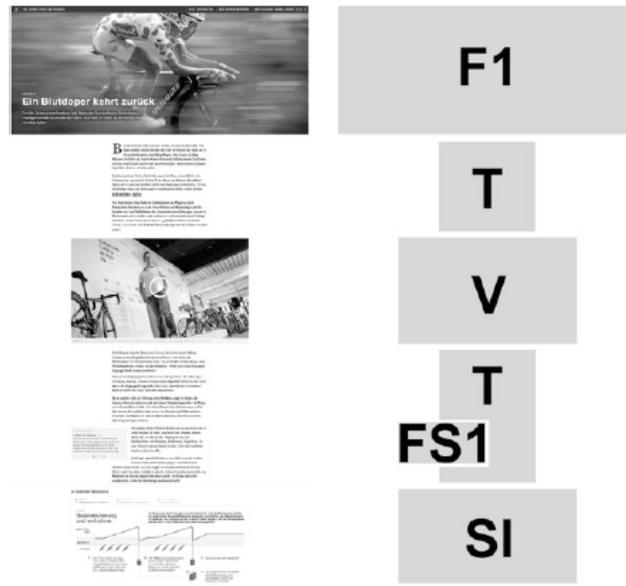


Figure 2.4 Prototypical representation by Godulla and Wolf [3]

### 2.1.8 DDS Layouts

DDS layouts are known for their versatility, allowing for effective segmentation and partitioning. The concept of layout compositions draws inspiration from data comics, where it uses a juxtaposition of visual elements. In data comics, panels, and gutter play a central role in the field. Saraceni describes panels as frames capturing frozen moments [55]. Another study by Bach et al. describes them as frames that encapsulate visual elements [4]. Spacing also plays an essential role in comic-style layouting. Saraceni calls the blank space between the panels a gutter. Sacreni’s study argues the importance of a gutter since it is the filling space between the visual elements. Therefore, they force readers to guess the missing parts to reconstruct the flow of the story [55].

This similarity between data comics and DDS showcases how comics’ sequential and visual nature can effectively communicate through the narrative structure. Bach et al. and Zhao et al. extend the notion of data comics for DDS. They investigate aspects like partitioning and sequence [4,41]. Bach et al. propose a design space that offers different layout compositions like linear, branched, network, parallel, grid, grouped, tiled, annotated, and large panel [4].

According to Zhao et al., data comic offers sequential panels organized into one-dimensional tiers. However, one limitation in Zhao et al.’s model is that enforcing panel positions can hinder the flexibility of DDS layouts [41]. Figure 2.5 shows the panel layout variations proposed by Bach et al. [4]. As we move on the spectrum of nonlinear to linear, the encompassing panels gradually shift to a highly partitioned style.

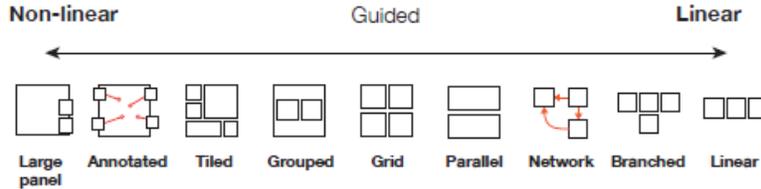


Figure 2.5 Panel layouts by Bach et al. [4]

### 2.1.9 DDS Taxonomies

Some studies in the field of DDS propose the development of all-in-one taxonomies that aim to address multiple aspects of DDS. These are primarily descriptive works with multi-level dimensions that inform future studies and understanding of DDS. Among these taxonomies, narrative patterns are low-level narrative devices toward a specific goal individually or in combination with other patterns [20]. Narrative pattern classifications come as a higher abstract classification for transition types. Although both describe the change in a story, narrative patterns explain more layers of a story. The narrative patterns consist of overall arrangements with broader transitions. Lan et al. propose narrative patterns for time-oriented stories, which represent the natural ordering of the events in a story. They count six patterns: chronology, trace-back, trailer, recurrence, halfway-back, and anchor [12]. Bach et al. group five major pattern styles in DDS: argumentation, flow, framing, emotion, and engagement. They describe narrative structure based on the non-measurable attributes, e.g., emotion [20].

Another taxonomy by Bach et al. introduces a design space for data-comic design patterns. Their model is a dual dimension space that connects different content relations (narrative, temporal, faceting, visual encoding, granular, and spatial) with different panel layouts described in Section 2.1.8 [4]. As a result, they connect certain arrangements and possibilities to these dimensions, although these recommendations are not enforced. Yang et al. propose a design space for creating stories. Inspired by Freytag’s pyramid structure, their model comes in three stages: setting, resolution, and rising-climax. Each stage has a set of narrative patterns [13]. Mckenna et al. divide DDS into two main types of stepper (click to

progress) versus scroller (scroll to progress). They define a design space with seven factors: navigation input, level of control, navigation progress, story layout, the role of visualization, story progression, and navigation feedback [14].

The taxonomy by Segel and Heer classifies different genres of visualization in DDS. They mention the genres: magazine style, annotated graph/map, partitioned poster, flow chart, comic strip, slide show, and film/video/animation. Each of these genres offers distinct approaches to visual narration. They also include the messaging in visualization to convey observations and commentary to viewers through text fields (labels, captions, headlines, annotations) or more extensive descriptions (articles, introductions, summaries). The problem regarding their work is separating the interactivity techniques in the narrative structure dimension and visual effects (transitions and highlighting) in the visual narrative dimension [9]. Stolper et al. propose their taxonomy through an analysis of various asynchronous DDS, categorizing them based on the techniques employed in four categories: communicating narrative and explaining data, linking separated story elements, enhancing structure and navigation, and providing controlled exploration. They also establish connections between their classifications and techniques from the previous work [9], further enriching the understanding of DDS storytelling techniques [11]. Ghidini et al. extend and reshape the taxonomy of the recent research [9] by adding a timeline to the genre and additional techniques to the interactivity. They also added audio to the messaging using another study [11] to their taxonomy [16]. Additionally, Ojo et al. explore DDS's design space and options by reviewing journalistic-related literature [15]. Lastly, Brehmer et al. delve into a design space specifically for timelines, highlighting the dimensions of representation, scale, and layout contributing to expressive DDS with timelines [17].

These taxonomies, design spaces, and classifications collectively contribute to exploring and understanding DDS, providing frameworks for analyzing narrative patterns, visual strategies, and interactive elements. By studying these diverse dimensions and approaches, researchers and DDS authors gain insights into the effectiveness and versatility of DDS narrative structure and design practices in DDS. To build a taxonomy, most studies' methodology comes after analyzing different DDS. The problem regarding this approach is that these studies dissect the DDS narrative into different parts, but it is impossible to build a visual narrative structure using all these parts. Therefore, these studies do not propose any visual approach for describing the DDS narrative.

### 2.1.10 DDS Authoring Tools

Within the realm of DDS authoring tools, a significant proportion focuses on the final phase of the process, which is the publication of DDS content. Lee and Riche argue that having a holistic tool to facilitate everything from data analysis, generating content, layout, and publishing comes with a price [39]. Besides having an extensive learning curve or even an unpleasant adaptability, it may not serve the purpose for every scenario since newsroom requirements keep changing. Regarding prototyping and storyboarding, some DDS publishing tools also facilitate the prototyping and storyboarding process.

epSpread by Walker et al. provides storyboarding in visual analytics with empty panels and annotation. They don't provide more customization for DDS, making it ineffective for current newsrooms requirements [25]. Gratzl et al. provide a tool that starts from data analysis to exporting a story. Vistory, as they call it, is an interactive presentation style of stories that progress with audience interactions [56]. The use case of their tool is closely related to data analysis and annotating visualization. Therefore it lacks any visual solution regarding structuring the DDS narrative. DataToon, on the other hand, gives complete freedom to the user by letting them have full control over the content on the canvas, interactions, and the design. Inspired by data comics, DataToon focuses on storyboarding at its essence; they let the audience provide their sketching with a pen, touch gestures, and the right dose of entertainment. The users are able to create their storyboards and customize them with their data and annotations. This approach is satisfying to designers because they are the core personas behind the visual decisions of DDS. To involve other personas in the story design process, they must fundamentally understand the DDS narrative structure. The results of their storyboards are close to data comics or infographics [57].

Conlen et al. put rapid prototyping as the main objective by combining notebooks and literate programming. Their proposed product, Idyll Studio, supports a specific markup language that generates DDS with custom styling. The representation of the DDS narrative in their work is based on the WYSIWYG strategy since they have edit in place feature. Since they represent DDS structure by a markup language, the first concern comes from a lack of specific knowledge regarding this tool. Their result shows their markup language is more adaptable than current basic web technologies like CSS or JavaScript. Although the range of different narrative structures seems not satisfying for newsroom standards, the lack of visual communication devices in their tool limits the number of personas that can contribute to story design [23,58]. Similarly, Satyanarayan and Heer propose Ellipsis by offering a domain-specific language for authoring DDS with a graphical interface. They define the concept of scene and sub-scene, linking them through user-driven events. They bind data changes to

these events as DDS progresses. Their model lacks of any representation of DDS narrative structure, serving a specific type of directed storytelling. [24].

VizFlow is another tool that targets rapid prototyping by providing a quick templating system for the layouts with the text-chart link structure. These layouts include side-by-side, snippets over a chart, pinned charts, long form, and snapshots. Their tool supports text editing, replacing visualizations, and sequencing these different layouts. In addition, their tool lacks any mechanism to support authors in their early story design process. In other words, since they do not provide a visual structure for the DDS narrative without any content, VizFlow cannot provide visual communication in the storyboarding process and idea generation. Although their paper provides a schematic depiction of these layouts, their tool only utilizes this representation as icons [5]. Although we support the idea of providing ready-to-go templates to see the result faster, in some cases, the lack of any flexibility toward DDS story direction prevents the DDS authors from exploring more alternatives. Figure 2.6 shows the environment of VizFlow.

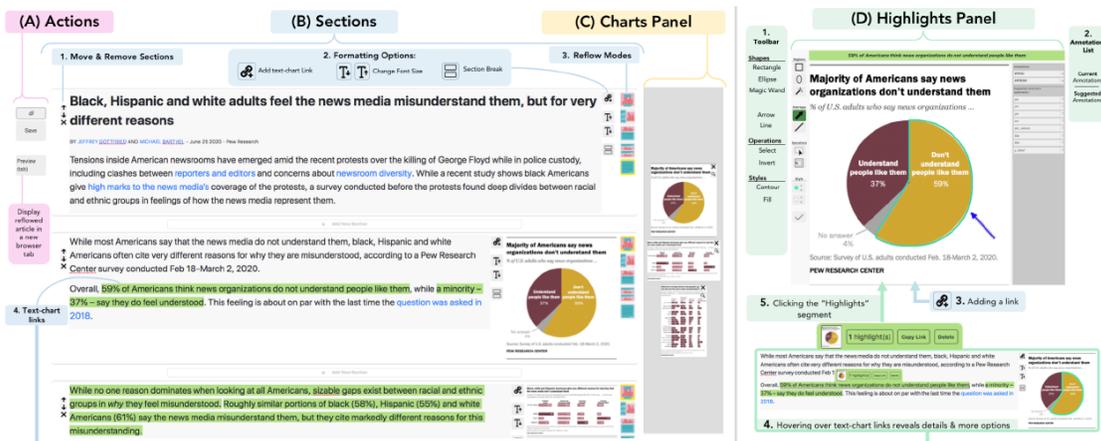


Figure 2.6 VizFlow by Sultanam et al. [5]

Morth et al. propose ScrollyVis Editor, a tool for storyboarding sequenced scene (shots) style DDS that supports logic-based nonlinear structure. They indicate that they target scrollytelling, where the audience only progresses through scrolling and clicking. Their tool contributes specifically to medical science to facilitate storytelling for non-technical users. Therefore, the inadequacy in providing a structure for the DDS narrative remains a significant challenge among newsroom professional authors. Figure 2.7 shows the environment of ScrollyVis Editor. Zhao et al. propose ChartStory, a tool for creating interactive portioned infographic DDS. Inspired by a study on layouting and partitioning [4], they provide rich interactive visualizations to ensure their exported DDS convey many different storytelling

scenarios. However, with a lack of story flow and smooth scrolling experience, today's industry expectation will be compromised [26].

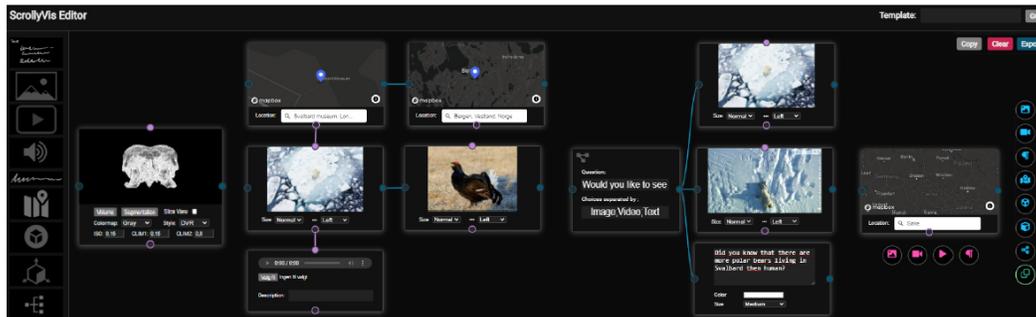


Figure 2.7 ScrollyVis Editor by Morth et al. [6]

Another study by Brehmer et al. provide an authoring tool to make various timelines visualizations in a storytelling format. Their work does not support different DDS narrative structures but differentiates between the concept of timeline and storyline [17, 59]. Finally, Obie et al. propose a tool for rapid data analysis and visualization with the help of a graph structure that combines visualization nodes with a wide list of interactions to provide better visualization sense-making. Gravity++ follows a previous version of the same tool [7, 60]. Figure 2.8 shows the environment of Gravity++.

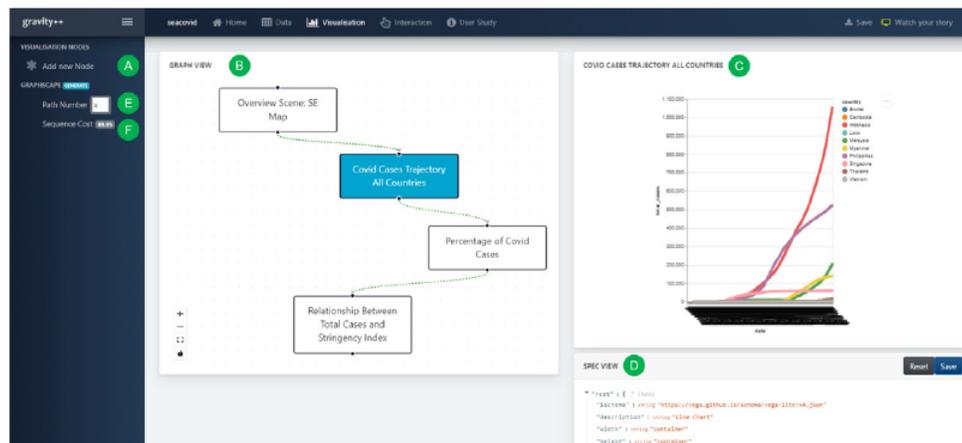


Figure 2.8 Gravity++ by Obie et al. [7]

Two major problems exist regarding the current prototyping and storyboarding solutions in DDS. The first problem is that these tools don't provide a semantic connection between dynamically changed elements. In other words, if a visualization changes to a static image, these visual effects are not intelligible through their system. The second problem is

they don't provide any structured scaffolding to start prototyping when the content isn't ready yet. This gap remains unaddressed since a visual representation of the DDS narrative structure hasn't been proposed. In addition, this proposed work aims to provide fundamental and integral knowledge of DDS narrative structure, linking it to the prototyping and storyboarding process.

## 2.2 Collaborative Process for Producing DDS

In this section, we review the collaborative activities behind producing DDS. First, we mention certain visual elements more suitable for DDS production workflow. We then name these collaborative processes and their adjustments in the context of DDS.

### 2.2.1 Visual Literacy

Visual literacy refers to the shared understanding and interpretation of visual information within the authors of DDS. It encompasses comprehending, analyzing, and communicating ideas and messages conveyed through visual representations. Visual literacy relies on collective knowledge and familiarity with visual elements, such as dots, lines, shapes, etc., to extract meaning, identify patterns, and make informed interpretations. Authors effectively navigate and communicate complex ideas through a common visual understanding, enhancing their overall comprehension and communication in visual contexts.

Using familiar visual elements like lines and arrows is essential in data visualizations. Since all personas know these elements, the outcome of using these elements gives a better chance for successful communication. DonDIS considers dots, lines, direction, and primary 2D shapes as fundamental elements for visual literacy, emphasizing their effectiveness in visual communications [61]. Some studies also put point, line, and area as the basic yet important visual marks or graphical symbols [62, 63]. Borner et al. indicate that these symbols have different properties like size, shape, color, etc. Although they discuss user studies that evaluate the effectiveness of these symbols, they are, in most cases, combined with studies that present these symbols subsequently [63].

The use of familiar visual elements, such as lines and arrows, in the production of DDS offers several benefits in visual communication. These elements serve as effective means for conveying directionality and guiding viewers through complex information [64, 65]. Arrows, in particular, have been extensively studied and are widely recognized for their ability to indicate change, movement, causality, and linkage [65–67]. Their distinct asymmetric form allows for easy recognition of directionality without distracting from the content they aim to

illuminate [65].

In visual literacy, using arrows as part of the visual language in DDS helps authors communicate narrative claims and guide viewers' understanding of the information presented [64]. The semiotic meaning potential of arrows has been explored in various scientific fields and is highly efficient in conveying complex ideas, ordering sequences of events, connecting elements, and indicating motion [65,67]. By incorporating arrows as familiar visual elements, authors can enhance their DDS's overall comprehension and communication, facilitating the shared understanding and interpretation of visual information within the target audience.

### 2.2.2 Collaborative Practices

In the production of modern DDS, various collaborative practices are employed to facilitate the generation of DDS narratives. These practices involve iterative and cyclic activities that intersect and overlap, resembling data science work practices and journalistic approaches [68]. These collaborative practices do not enforce any strict visual structure in DDS production. Even sketching, which is commonly used among scholars, does not come with rigid guidelines [69]. However, the visual impact of these collaborative decisions affects the final result and the workflow of DDS authors. One such process is the highly iterative nature of interrelationships among data acquisition, data exploration, and the generation of exciting story ideas [68]. This iterative approach allows for the refinement and improvement of ideas through repeated cycles of exploration and analysis [70].

Idea generation is an early yet crucial aspect of these collaborative practices. Among them, tinkering with data allows creators to preserve valuable aspects of the data and iteratively refine and rework what is not contributing effectively to the narrative [68]. Sketching and storyboarding, among the other practices, let the participants engage in visual communication as thinking aids to structure their thoughts [29]. With their ambiguous and rudimentary nature, sketches especially allow for multiple interpretations, re-interpretations, and the generation of new ideas [29]. Similarly, storyboards provide a visual framework for organizing and rethinking ideas, facilitating the exploration of different narrative possibilities [29].

A common challenge in the creative process is the tendency to fixate on a single solution or a narrow range of potential solutions early on. However, it has been demonstrated that this fixation limits the exploration of alternative possibilities [2,27]. To overcome this, parallel prototyping techniques are employed, which involve the early generation of diverse examples and the simultaneous exploration of multiple alternatives [70]. This approach has been found to yield higher-quality designs, promote diversity, and increase self-efficacy among designers [70].

### 2.2.3 Storyboarding

In the previous Section 2.1.10 we talked about various studies that adapted to storyboarding practice in their authoring tools [6, 25, 57]. In recent years, the creation pipeline of DDS has evolved. The more complex forms of DDS introduce extra steps toward idea generation, data analysis, design, and implementation. Therefore, bigger news publishers involve more personas with different specialties in DDS production. Evidence from studying the workflow of media outlets implies the existence of documentation practice among most DDS creators. Users' drafts vary depending on the complexity of different pipeline stages. For stories on the heavier side of data analysis, the team shares documents summarized with data analysis and insights. DDS creation workflow usually consists of edits, reviews, corrections, and improvements, meaning users must draft multiple versions of their work [68]. In addition, documenting DDS workflow brings benefits to archiving DDS. Archiving modern DDS has limitations since modern web standards are constantly changing. Many examples of DDS are no longer accessible or working correctly [71]. The archiving problem also creates a problem for DDS researchers since they cannot validate DDS-evaluated studies by themselves. Therefore, having a reference document to store a descriptive version of DDS is an effective way to make sure further edits and reviews are comprehensible to users.

Wahid et al. believe proper storyboarding prevents future design costs, giving a story the right direction [72]. Storyboarding as a collaborative process brings benefits for documenting DDS by creating side documents that involve strategically arranging data visualizations, text, and media elements in a sequence of panels or frames to convey the narrative effectively. Weber and Rall indicate that the importance of storyboards comes from providing a bigger frame of storytelling, preventing the team from getting distracted by details. They believe storyboarding and sketching are central strategies for promoting the collaborative process between different personas in DDS production. In addition, they suggest storyboarding is a proper way to convey non-linear deviations from the main path [29]. Furthermore, storyboarding prevents poor visual communication in DDS production, a limiting factor for a collaborative workflow. Although there are other documentation practices like sketching and using spreadsheets for data insights, storyboarding, in particular, represents a descrambled version of the story by providing the flow of information comprehensively [29]. Storyboarding, similar to data comics, combines text and visual elements to represent a flow of information [4].

Walker et al. describe the principles of storyboarding in the context of visual analytics, including viewpoint, composition, interaction, annotation, transition, and separability. The composition follows a storyboard template, featuring empty boxes for sketches, lines for text

descriptions, and space for associated details such as titles. The transition between storyboards involves the progression and arrangement of frames, often positioned side-by-side, with annotations and descriptions enhancing understanding. The placement of these panels is important to determine how the order is organized. Often, the storyboard panels are positioned side-by-side. Additionally, storyboarding should adhere to principles like annotability, interactivity, and separability. Annotability allows analysts to add text notes on visualizations to indicate important features. Annotability that adds information within panels should not be confused with captioning the panels. Interactivity enables the exploration of data within each panel e.g., zooming. Separability ensures that storyboard panels can be used independently, with reproducibility of static images and explicit representation of time periods and queries. Furthermore, they indicate that sketchiness is unnecessary for storyboarding for visual analytics, though it can be beneficial. They believe summarization is a more necessary task for storyboards [25].

In general, UX and film industry storyboarding solutions don't accommodate the features of DDS. Since the structure of general storyboards consists of panels in certain arrangements, these tools force separate panels when panels flow in various compositions in the many layouts examples. The high level of adjustments improves the designer's result, although considering DDS structure requirements from the beginning will result in a more adapted tool for the task. Storyboarding panels seem a different approach than WYSIWYG for prototyping and authoring DDS, but the DDS narrative structure should merge them to benefit both from the reusability of storyboards and the agility of prototyping DDS. Furthermore, storyboarding, prototyping, and sketching concepts become indistinguishable in some cases. Their common feature is brainstorming, which fosters a collaborative and iterative approach to idea generation and design process. Inspired by all these practices, we aim to combine visual features for DDS constructing elements to propose an integrated structure for DDS narrative.

## CHAPTER 3 PROPOSED METHODOLOGY

The previous Chapter reviewed the key aspects of the DDS narrative structure and its incorporation within the DDS authoring tools. We discussed the current state of visualizing narrative structure in the DDS studies and the prototyping and storyboarding systems in the currently available authoring tools. This Chapter proposes a *comprehensive design language for DDS narrative structure*. This design language contains a set of design rules that allow DDS authors to present the narrative structure.

### 3.1 Method

In this Section, we describe the process leading to the design language. The method we used for this process consists of three steps. First, we leveraged insights from the reviewed literature in Chapter 2. Second, we engaged in a series of brainstorming sessions with the authors of French newsrooms to validate the results of these studies. The brainstorming sessions further enhanced our understanding of the DDS collaborative process and brought us additional insights. These sessions provided the opportunity to gain firsthand feedback from DDS authors, contributing to a more comprehensive understanding of the DDS prototyping and storyboarding process, their requirements, and expectations. Lastly, as a result of these two steps, we concluded a multi-directional structure that helped us in the thinking process of developing the design language. Alongside these steps, we incorporated a deductive coding approach, starting from the first steps and expanding all the way to the last step.

#### 3.1.1 Step 1: Insights from Literature Analysis

As we reviewed the related studies on DDS narrative structure in Chapter 2, we approached this topic from a top-down perspective since we broke DDS narrative structure into its constructing elements like path structures, layouts, transitions, etc. Therefore, the qualitative information of these studies lets us perform a deductive coding process to analyze and extract insights in the format of tags (codes). These insights relate to the visual features of the DDS narrative structure. This process ensured the design language synchronized with the current proposed design solutions and taxonomies. The process subsequently examined the prototyping and storyboarding solutions through different authoring tools to extract more pronounced design directives. Utilizing the literature on narrative design and authoring tools was crucial to extracting these insights that helped shape the design rules of the design

language. As a result, we obtained a comprehensive understanding of existing knowledge and best practices. Leveraging the expertise and research of the current studies ensured that the design rules were established with a robust foundation of knowledge. This step enhanced the quality and validity of the design language by structuring our thinking process. The inclusion of these studies' domain confirmed that we deliberately avoided any bias toward specific design direction since our review collected various aspects of DDS narrative structure from a wide range of academic resources.

The key insights obtained from the literature on DDS narrative structure defined the original foundation of the narrative structure of DDS. The activities like the *narrative design*, *storyboarding*, *prototyping* and *brainstorming* are the major agendas in DDS production through the literature on DDS narrative structure and the authoring tools [3, 5, 6, 23–25, 70]. Other studies also, mentioned to *sketching* as a contributing activity for DDS production [13, 23, 29, 30, 35, 41, 52, 68–70]. In addition, to make sure the design language is compatible with the narrative taxonomies in the previous Chapter, we included *path structures*, *layouts*, *narrative patterns* and *design spaces* of DDS to our collected insights [3, 4, 9–12, 20, 35, 41, 46]. After deriving the proposed structure for the DDS narrative, we used these insights to initially assess the design rules. This step ensured that our result was compatible with the latest findings in DDS. *linearity* and author-driven DDS are vastly studied in modern journalism. Some studies suggest them as a preferred style of producing DDS by notable journals [10, 11]. Therefore, we included them in our insights. Although to have a comprehensive design language, it's necessary to support nonlinear DDS through various path structures. Our insights included *graph structure* to represent the macro level demonstration of DDS narrative structure [2, 3, 46]. We included *encapsulation* since it involves different layers of storytelling (macro, micro, inner narrative) [41]. *WYSIWYG* is another insight obtained from the literature to make sure the prototypes and storyboards are well understood by the different personas [54]. DDS represent *multimodality* depending on the data they represent [3, 10, 29, 30]. Therefore, we added this feature as an insight to our list. Inspired by encapsulation in data comics, we added *partitioning* to break big layouts into smaller parts [4, 41]. A *flow presentation* is essential for the design language to demonstrate the direction of progressing information in DDS [35]. On the micro level, transition reflects how data circulates in a document [2]. It is also important that the whole structure of the design language is aligned with a common *primer literacy* between all personas. The simple visual elements like dots, lines, arrows, and area improve visual communications [61–67].

In search for the aspect of DDS arrangement with more pronounced visual directives, several studies and authoring tools referred to *separable scenes* structure in DDS [7, 9, 11, 13, 24, 25, 33, 35, 51]. The next insights come from Scrollytelling DDS, which needs audience interaction

to progress. These forms introduce visual elements on their timelines by *chronological order* rather than time-based order. The concepts of *storyline* and *timeline* define how authors arrange elements in a sequenced structure [2, 6, 11, 12, 17, 19, 21, 24, 31, 33, 35, 39, 44] [13, 15, 41, 69]. The insights for parallelism come in different layers as *parallel layout*, *parallel transitions*, *parallel paths* and *parallel narrative* [2–4, 10, 13, 21, 35, 41, 50]. Another key insight for this language is *wireframe prototyping*, based on the higher level philosophy, WYSIWYG [3, 30]. In this regard, none of the current authoring tools present wireframe prototyping, which is the main characteristic of our design language. To cover the concept of DDS transitions, smaller forms of flow presentation appear with the help of staging technique [2, 17, 35, 50–52]. We concluded the insights like *visual connectivity* and the use of *states and arrows* from various studies that cited the benefits of them in visual communication [2, 44, 61–63]. Finally, many studies referred to *annotating* and *sub-scene* as inner parts of DDS scenes [5, 9, 11, 17, 24, 25, 30, 31, 35, 39, 42, 49] [41]. The terms *charts*, *interactivity* appeared in almost every resource; therefore, we added them intuitively.

### 3.1.2 Step 2: Brainstorming Sessions

Through three brainstorming sessions with four DDS authors (one designer and three engineers) in the news industry, we measured the practicality of the key insights from the previous step in real case scenarios. The integration of industry professionals' insights through these sessions added an empirical layer to the findings of the previous step. We conducted these sessions through Zoom online meetings, each for one to two hours. Engaging in these collaborative idea-generation sessions benefited us from additional perspectives and insights from the industry. We listened to their requirements and expectations, which helped us to prioritize specific keywords suitable for their prototyping and storyboarding practice. The brainstorming sessions provided an opportunity to evaluate the quality and the applicability of the derived design rules and requirements identified in the previous step. By incorporating brainstorming sessions into the process, this proposed work became a collaborative endeavor, drew on collective expertise, and enabled the integration of diverse perspectives. This iterative communication ensured that the design rules and requirements derived from the process were robust, practical, and responsive toward the industry's expectations from the DDS narrative design language.

On various meetings on brainstorming sessions with Le Devoir professionals, they indicated "*We usually talk about getting faster at prototyping our versions of a story*". This priority indicates the participants focuses on prototyping and cloning stories more than storyboarding, although they might not be thoroughly familiar with the scope of each one of these tasks

against each other. Despite several studies pointing to the difficulty of producing highly interactive DDS like scrollytelling by several studies [5, 10, 73], our participants had already developed a template to produce a prototype of their story. They preferred to use specific scrollytelling templates for their special interactive news editions. However, for custom-design stories, authors need to spend significant time reshaping their stories. One participant from Radio-Canada developed a custom notebook to document the process of DDS production to have a flexible data control for later adjustments. The participants' need for custom tools for rapid prototyping and better documentation showed the necessity of such a system for prototyping and storyboarding DDS. The participants indicated that they did not try different structures of their DDS mostly because they are "*time costly*" to produce. Some studies mention the problem associated with fixating on a single design solution for authors [2, 27]. Therefore, the participants were eager to see the result of combining this wholesome dual approach of prototyping and storyboarding. Participants recognized a handful of popular patterns and layouts in famous media outlets and their specifications. The brainstorming sessions revealed that the team is less likely to spend time preparing more advanced forms of graphics like data gifs or data animations to represent transitions. Participants' information revealed that the team put visual elements on their early prototype based on the amount of details they decided to put into their prototypes.

### 3.1.3 Step 3: The Corpus of Tags

By analyzing the collected tags, we grouped the tags and put the similar subordinate entities in a mutual group in no specific order. We structured these collected tags from the previous steps into a multi-dimensional structure to complete the deductive coding process. The result presents a corpus of the essential tags for proposing a comprehensive narrative structure. We then used this structure in our thinking process to derive the design rules for our proposed DDS narrative structure. Extracting design rules from the corpus of data was an iterative thinking process and design activity that evolved through rigorous analysis and fruitful collaboration between reviewed literature and brainstorming sessions.

Based on this corpus of tags, the study drew the conclusions that lay the foundation of the thinking process for developing the design language, the prototyping, and storyboarding solution for DDS. The results of this analysis can be found in Table 3.1. The entities of Table 3.1 are not semantically exclusive since the linguistic and semantic similarities between concepts like storytelling techniques, story design, and narrative structure are not exclusive. However, they cover the whole subject from different perspectives. Each group addresses specific aspects related to the creation and design process of the narrative structure of DDS. These

groups form a comprehensive agenda, conveying essential details to develop such a language. Besides comprehensive coverage, they also logically progress from macro-scale spectrum to sub-scene level features. If a concept has been proposed from different perspectives, we put variations in its corresponding group. After developing the design language, we analyzed our rules to ensure they are adaptable to different paths, layouts, patterns, and taxonomies in the literature. These tags come in the following six groups:

- *Goal*: Goal shows the big frame directions toward defining the design language.
- *Compatibility*: Compatibility relates to the compatibility of the design language with the current studies regarding various path structures, layouts, narrative patterns, design spaces, and best practices.
- *Basis*: Basis defines the fundamental strategies with which the design language should align.
- *Arrangement*: Arrangement defines the strategies for arranging and composing different elements in the design language.
- *Transition*: Transition defines the strategies for representing a transition in the design language.
- *Scene*: The Scene defines the detailed functionalities related to the scene content of a DDS in the design language.

## 3.2 Proposed Representation for DDS Narrative Structure

In this Section, we propose the result of the previous Section’s process with visual definitions incorporated with design rules for DDS narrative structure. These visual directives create a comprehensive design language that splits the DDS narrative structure into three distinct layers (Macro, Micro, and Inner-Narrative). Among these layers, we define several visual elements on the Micro level of the DDS narrative structure. The combination of these layers introduces an integrated narrative structure for DDS. In the following Sections (3.2.1, 3.2.2), we define these layers, elements, and design rules.

### 3.2.1 Definitions for DDS Narrative Structure

We propose the following definitions for the layers of the DDS narrative structure.

Goal
narrative design
storyboarding
prototyping
brainstorming

Compatibility
paths
layouts
patterns
taxonomies

Basis
linearity
graph structure
primer literacy
encapsulation
WYSIWYG
multimodality
partitioning
flow presentation
parallel paths

Arrangement
separable scenes
chronological order
storyline design
parallel layout
wireframe prototyping

Transition
states & arrows
staging
parallel transitions
visual connectivity

Scene
timeline
parallel narrative
sketching
interactivity
annotating
charts
sub-scene

Table 3.1 The corpus of the tags obtained from Step 1 and Step 2

- *Macro Structure*: The macro structure represents the DDS narrative structure on the level of DDS path structures. This level is inspired by the same terminology used by various studies [2, 35, 37, 38, 40] which resembles divisible plots (paths) of a story. This level is the highest level of DDS representation, encompassing all DDS scenes and their constructing elements.
- *Micro Structure*: The micro structure represents the DDS narrative structure on the level of DDS scenes. This level is inspired by the same terminology used by various studies [2, 35, 38, 40], which resembles divisible story episodes. The micro structure is a descendant of the macro structure. In other words, each plot (path) is divisible into multiple episodes (scenes). Since in linear author-driven DDS, the audience only traverses one directed path, the macro structure only has one plot (path). This level further breaks down DDS scenes into smaller components called a *placeholder* (Section 3.2).
- *Inner-Narrative Structure*: The inner-narrative structure represents the DDS narrative structure on the level of placeholders. We define this layer after proposing the same terminology in Chapter 2 where the story’s content is no longer divisible into smaller parts that independently communicate meaningful data. (e.g., an interactive layered chart has an inner-narrative structure while a static chart does not).

In addition, We propose the following definitions for the visual elements of the DDS narrative

structure. These elements exist on the micro level of the DDS narrative structure.

- *Placeholder*: A placeholder is a schematic depiction of visual content. This visual element represents either a portion or an entire visual scene. The representation of a placeholder is an empty frame marked with a symbol of its modality (content type) in the center. On the theoretical level, a placeholder is an encapsulated entity. It can encompass one to many (n) placeholders. These new descendant placeholders represent their own modality separately. A placeholder's size proportionally resembles its counterpart's original content size, although authors may ignore the precision for rapid prototyping and storyboarding. A long graphic with a higher length than the visual frame results in long proportional placeholders. Placeholders depend on their position and their arrangements, come in different types, including *primary*, *overlaid*, *affixed*, *stacked*, and grouped types (Section 3.2). Figure 3.1 shows a placeholder representation.



Figure 3.1 Placeholder

- *Storyline*: A storyline is a unidirectional arrangement of placeholders in chronological order based on precedence in appearance. The storyline axis represents the progression in the events of DDS.
- *Block*: A block is a parallel formation of storylines to divide stories into smaller parallel parts. A single storyline with no other parallel elements counts as a separate block.

### 3.2.2 Design Rules for DDS Narrative Structure

The design rules of the narrative structure go into four main categories: Expression, Replication, Narration, and Connection. These design rules exist on the micro level of the DDS narrative structure. With these rules, authors can replicate a wireframe prototype called *replica* for the entire story. With this model, presenting a schematic version of the story precedes the process of prototyping to the early stages of the design process, with placeholders representing the content modality. In this regard, spaces, scales, ratios, and lengths

are adjustable to the viewer’s perspective. Authors incorporate these rules while avoiding unrecommended collisions and visual clutter. Table 3.2 shows the structure of these design rules.

- *Expression*: These design rules refer to the rules associated with the visual expression of the content and the behavior of each individual placeholder.
  - *Modality*: The modality of a placeholder varies e.g., text, image, visualization, video, map, raw data (including data tables), input, and data video. The modality symbol is not mandatory but recommended for representing the content role. Figure 3.2 shows different modality types in our design language.

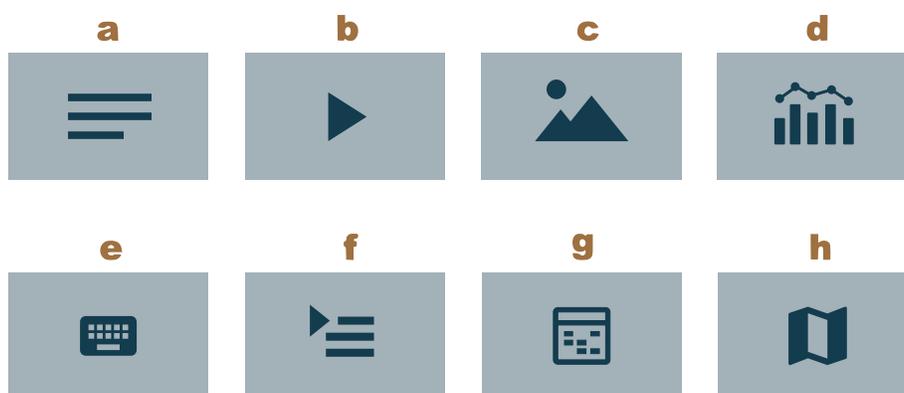


Figure 3.2 Modality types: (a) Text, (b) Video, (c) Image, (d) Visualization, (e) Input, (f) Data Video, (g) Raw Data, (h)Map

- *Expressive Symbols*: Each placeholder may have one to many (n) Expressive Symbols positioned over to express different features of the visual element. The symbols indicate the visual element’s inner-narrative property, including interactivity, effect, carousel, and floating symbol. Figure 3.3 shows these Expressive Symbols.
- *Replication*: Replication refers to all the design rules associated with the primary placeholder’s structure and the positioning of their related elements. A *primary placeholder* is a placeholder that dictates the positioning of all the related elements associated with it. A particular type of primary placeholder is called a full-screen placeholder that expands in both directions to fill the entire viewport. The rules of Replication include Affixing, Overlaying, and Stacking. These rules introduce new types of placeholders related to primary placeholders.

Expression	Modality
	Expressive Symbols
Replication	Overlaying
	Affixing
	Stacking
Narration	Storyline Foundation
	Block Formation
	Group Composition
	Frame Fixation
Connection	Transition
	Progression
	Execution
	Aggregation

Table 3.2 The design rules structure

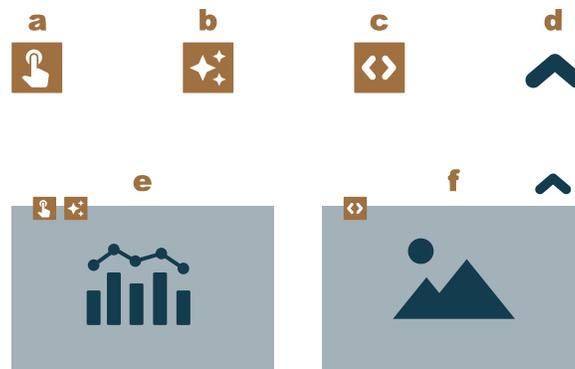


Figure 3.3 Expressive Symbols: (a) Interactivity, (b) Effect, (c) Carousel, (d) floating, (e) A Visualization placeholder with Interactivity and Effect symbols, (f) an Image placeholder with Carousel and Floating symbols

- *Affixing*: Every placeholder is divisible into one to many (n) affixed descendants. The *Affixed placeholders* are not divisible further. They attach to the surface of an outer encompassing placeholder, e.g., annotations and small visual cues. An affixed placeholder has a relative aspect ratio representing its surface compared to its parent. The representation of an affixed placeholder is an empty frame marked with a symbol of its modality positioned over the surface of its parent element.
- *Overlaying*: Each primary placeholder may be followed by one to many (n) aligned placeholders called *overlaid placeholder*. They come to the scene by crossing over elements. They are the subsequent placeholders, sliding over their precedent placeholders. They are the subsequent placeholders, sliding over their precedent placeholders. The representation of an overlay placeholder is an empty frame smaller than its primary placeholder, marked with a symbol of its modality, positioned in the following of its parent element. Overlaid placeholders are visually separated from their precedent element.
- *Stacking*: Each placeholder may stack multiple layers of visual elements. In this case, they are also *stacked placeholders*. To visualize them, instead of one frame, two stacked frames should be used that are slightly shifted against each other. A stacked placeholder cannot be divided further. Since stacking items puts some of them out of visual sight, stories need more interaction from the user. This concern is explicitly stressed in author-driven stories as a contradiction.

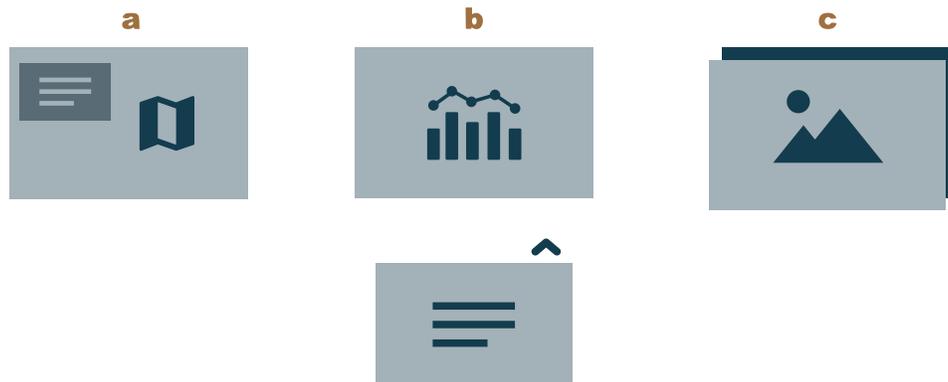


Figure 3.4 Replication: (a) Affixing, (b) Overlaying, (c) Stacking

- *Narration*: The narration describes all the design rules associated with the arrangement and movement of different placeholders in combination with each other. We further separated the narration into four design rules: Storyline Foundation, Block Formation, Group Composition, and Frame Fixation.

- *Storyline Foundation*: To create a storyline, first placeholders should align in one direction by their precedence in appearance. The length of a storyline is determined by its first and last placeholders. A *degree of Storyline* is a pair of numbers (i, j) called i to j, showing the number of the placeholder(i) crossing over to the number of placeholders (j) through the whole thread of the storyline. A storyline may have multiple Degrees of Storyline as the layout changes through the story. Figure 3.6 (a) shows the demonstration of Storyline Foundation.
- *Group Composition*: A Group Composition is a united arrangement of multiple placeholders. A Group Composition indicates the visual elements in the same group appear, progress, or move together. To present grouped placeholders, their Connection and Frame Fixation (Section 3.2) must be simultaneous. The grouped placeholders are suitable options to present partitioned layouts, e.g., data comic style, juxtaposition, and separated shots. Figure 3.5 shows the Group Composition in both directions.

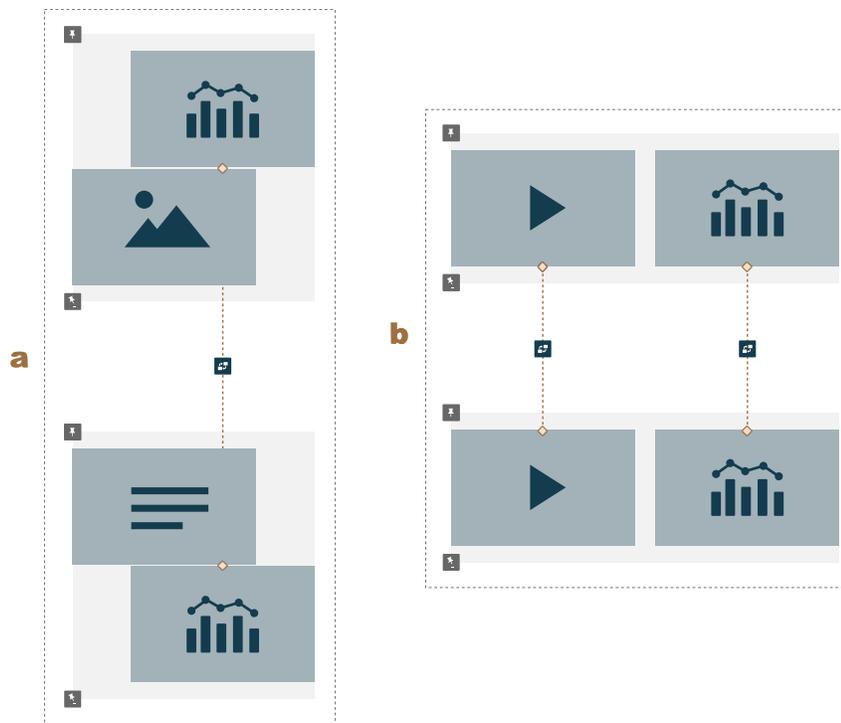


Figure 3.5 Group Composition (a) vertical, (b) horizontal

- *Block Formation*: To form a Block, equally distanced storylines (n) should be placed against each other. A *degree of Block* is the number of parallel storylines per block. The Degree of a block can be single (n = 1), double (n = 2), triple (n

= 3), etc. The position of a placeholder is relative to the opposite counterpart, depending on their precedence in appearance. Parallel occurrence means two placeholders appear almost simultaneously in the narrative. A placeholder against a long graphic seeks to accurately present its position compared to framed graphics since its visual element targets a specific location on the longer side. Each block breaks where the number of concurrent storylines changes. Each DDS consists of multiple consecutive blocks. Therefore, in each story, there may be multiple combinations of Storyline Foundation and Block Formation in different sections. Figure 3.6 (b) shows the demonstration of Block Formation.



Figure 3.6 Narration: (a) Storyline Foundation, (b) Block Formation

- *Frame Fixation*: A Frame Fixation is a portion of a storyline that sticks to the viewport to prevent progression in the narrative flow by scrolling or other interactions. With each Fixation the normal flow of DDS interrupts and then continues. A fixated area can grow in both directions using Block Formation and Storyline Foundation to align placeholders. Each Fixation has starting and finishing points that indicate the fixated area's beginning and end. For DDS with separated sequenced scenes (shots), the Fixation area begins and ends with each placeholder. In the case of any parallel visual elements, the fixated area goes longer as an in-

indicator of Fixation time against other elements. Each storyline can have multiple (n) consecutive fixated areas that may overlap. The beginning of a fixated area is always determined by a placeholder called first pinned. To visualize the Frame Fixation, a rectangular shape starting from the first pinned covers all the area behind the proceeding elements until it reaches the finishing point. Two visual symbols, pinning in and pinning out, are positioned at the fixated area's start and end. Figure 3.7 shows Frame Fixation.



Figure 3.7 Frame Fixation: (a) Frame Fixation starts with a Primary placeholder and finishes after an Overlaid placeholder., (b) Frame Fixation starts with a Primary placeholders and finishes after another Primary placeholder., (c) Frame Fixation starts with a Primary placeholder and finishes after a certain time.

- *Connection*: A Connection represents a change between two continuous placeholders. Placeholders are connectable only if their connection path does not need to collide with any placeholder with the same type as the two ends. There are four types of Connections: Transition, Progression, Aggregation, and Execution. To visualize a Connection between two placeholders, a dashed straight line exits one side of the source element and enters the opposite side of the destination element while crossing below all the placeholders in between. At any form of Connection, the collision points of the line to the sides of the source and the destination placeholders are marked. Two ♦ signs are necessary to distinguish the two ends of the connection. Midway, over the Connection line, a symbol represents the type of connection. Figure 3.8 shows different types of Connections.

- *Progression*: A Progression connection describes the changes within the states of

the same graphics. To progress, the base structure of the first state should remain the same throughout the progression. This convention applies to two different modalities as well as two different visual elements within the same modality, and cannot use this design rule.

- *Transition*: A Transition connection describes the changes within the state of different graphics. Opposite to the progression, transitions happen on the occasion the change cannot be considered as a simple or advanced progression.
- *Aggregation*: Aggregation means the change happens by merging or juxtaposing another visual element.
- *Execution*: An Execution demonstrates collecting input from the audience into rendering the visualized result.

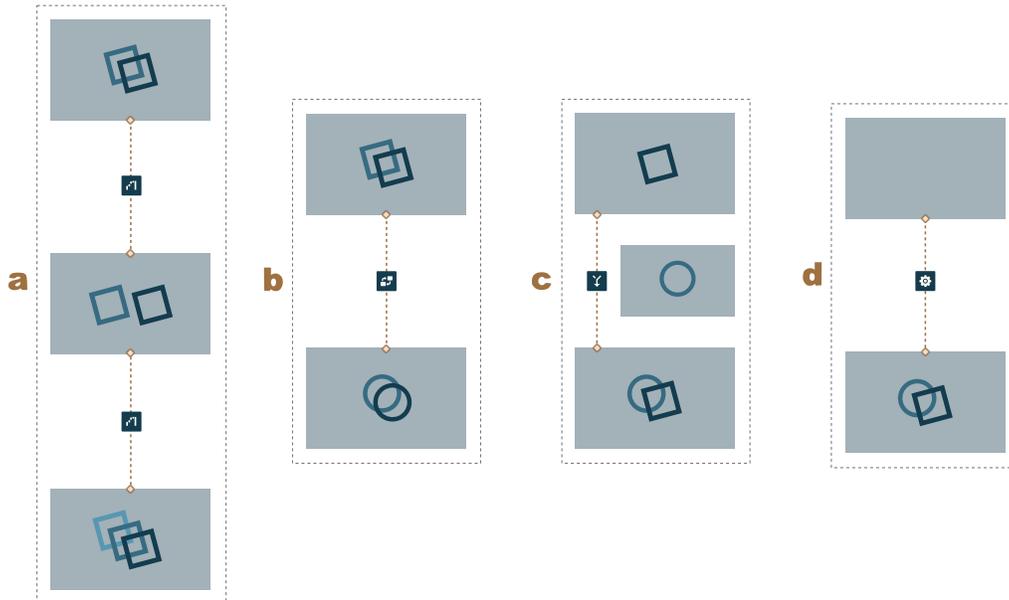


Figure 3.8 Connection types: (a) Progression, (b) Transition, (c) Aggregation, (d) Execution. The Modality of the placeholders is replaced to demonstrate the characteristic of the content change schematically.

### 3.2.3 Macro Structure

A comprehensive solution for DDS narrative structure requires conveying different path structures of DDS. DDS path structure defines the DDS narrative on the macro level. In a nonlinear DDS path structure, the sequence of scenes may create a loop. In this work, we suggest using the branched out structure proposed by Godulla and Wolf and Seyser and Zeiller with

a modification. The branched out structure is a form of a directed graph with a tree structure path where each node can only traverse through its parent or children. Since nodes resemble DDS scenes, the consecutive scenes should be connected. This is contradictory, if one scene has an extra connection with its siblings or cross scenes, the structure is no longer a tree structure since it creates a loop. To solve this, we propose keeping the tree structure by adding duplicate scenes in each exclusive branch. Figure 3.9 shows how to change a directed graph with loops to a tree structure.

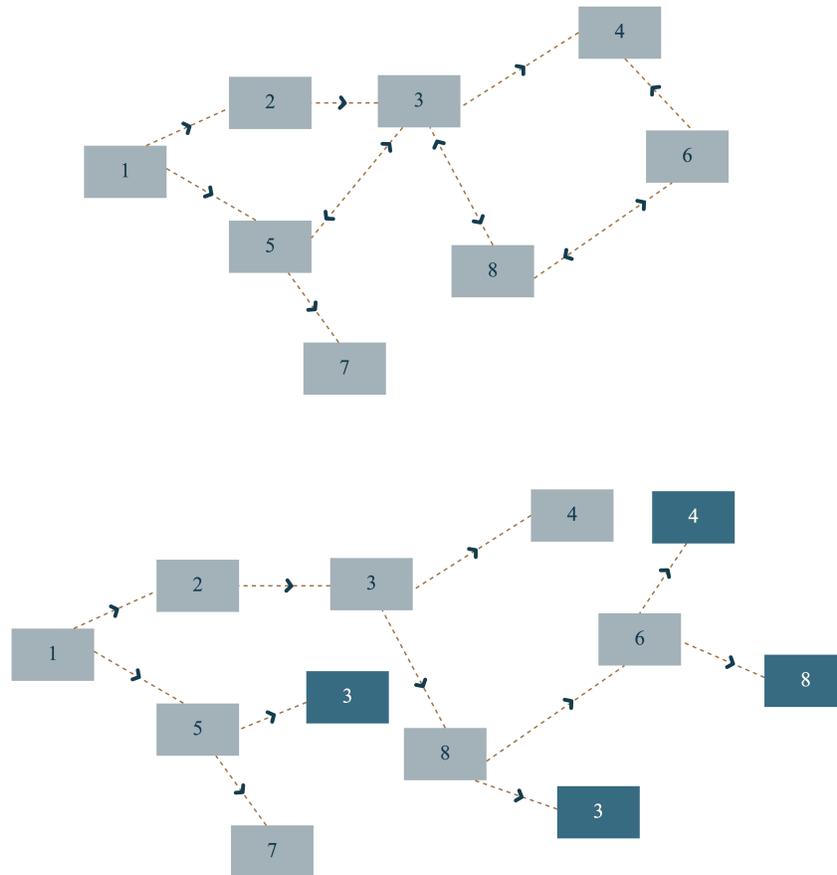


Figure 3.9 Macro structure solution for the path structures with looped directed graphs

If we apply the same solution to our design language, we visualize each episode of DDS with the common parent aligned with each other with a small gap. If each episode has parallel storylines, the gap increases to separate episodes. A heavy-stroked line connects parallel episodes. Using this method, a tree structure emerges after creating the macro structure. If a similar block or placeholder repeats throughout the entire document, the design language keeps the duplicate in exchange for keeping the design coherent. In general, it is advised to use the WYSIWYG design approach since it is intuitive and used by design tools [54]. This

method represents each episode of DDS through a linear structure by removing any loops in their nonlinear structure. Linear structures are easy to follow. Therefore, the readability increases through the early stages of story design. Figure 3.10 shows an example of DDS with multiple paths in a tree structure format.

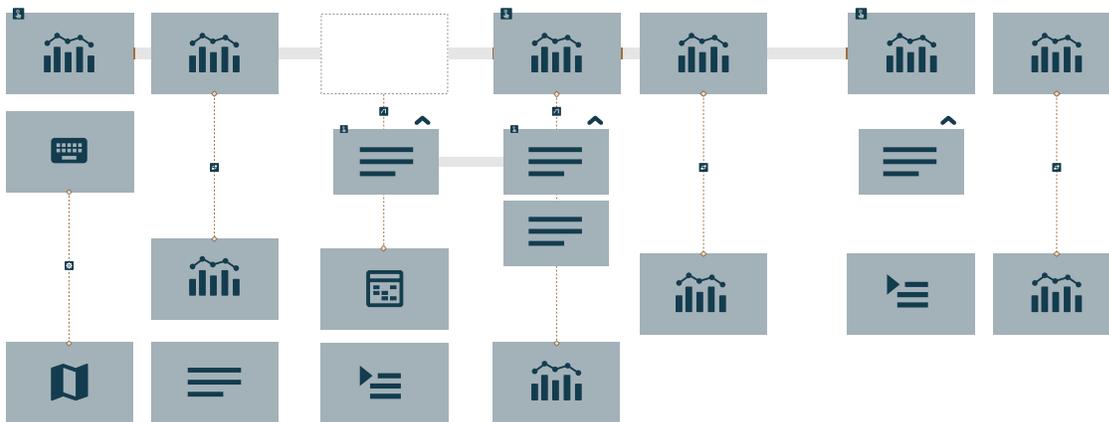


Figure 3.10 Macro Structure proposed by our design language

### 3.2.4 Inner-Narrative Structure

The Expressive Symbols design rule is created to explain the content of the inner-narrative structure. In each DDS design, there is a point where the author decides to stop breaking down the design. E.g., authors break down juxtaposition or comic-style layouts into simpler elements while avoiding breaking a bar chart into smaller parts since these parts do not project any meaning on their own. These meta symbols make a DDS expressive since it adds visual features like interactivity, effect, floating, or carousel. If the structure inside a placeholder is an interactive multi-path element, it is best to consider the root placeholder as a divider node of the story, which takes its own path. In this case, the separate path appears aligned with the multi-path placeholder, separated by a dashed line. Both of these approaches are acceptable on their terms. Depending on the complexity of the inner narrative path, authors decide to which extent their prototype should be expressive.

## 3.3 DataStoryDesign: A Prototyping and Storyboarding System for DDS

To showcase the capabilities of the design language for prototyping purposes, we present DataStoryDesign, a prototyping system specified for narrative design in DDS. DataStoryDesign is carefully adapted by the language proposed in 3.2, which outlines DDS's key elements

and design rules. DataStoryDesign offers a schematic design language like a storyboarding tool specifically designed for DDS narrative design.

### 3.3.1 Requirements and Compatibility

We analyzed the authors' key expectations from a prototyping perspective. Through the brainstorming sessions (Section 3), we thoroughly reviewed the collaborative process in the DDS production chain. The result suggests a set of design considerations based on the participants' workflow, design decisions, and UX limitations. These limitations suggest ensuring essential functionalities like creating, editing, and discussing a prototype or storyboard are happening all in one sight.

In addition, we analyzed up-to-date projects at Le Devoir. This project highlighted the extent to which the design language's design rules apply to their needs. Also, to reduce the process of introduction and onboarding for this language, we decided to keep the main design rules (Expression, Replication, Narration, Connection) to the extent of the participants' needs. This consideration is important if later studies decide to develop an adaptation or an onboarding guide in multi-stages for such a language.

We did not put affixed placeholders in DataStoryDesign since parent placeholders represent a bigger snapshot of story elements. Therefore, they can show the structure from a further perspective as a single unit. In addition, sometimes, in a visual scene, authors have multiple options to assign a visual role to an element, e.g., considering a visual element as grouped, encompassing, or separated elements. Authors may translate gaps, background color, pattern, or fabrication differently each time. Some layouts with affixed placeholders are convertible to multi-storylines instead.

We customized the settings of the Degree of a Storyline in the Storyline Foundation ( $n = 1$ ) and the Degree of Block in the Block Formation ( $n = 2$ ), based on analyzing multiple projects in the current workflow of the participants. In addition, one of the limitations associated with UX was keeping the commenting, the canvas, and the resources sections all in one view without sacrificing too much width. DataStoryDesign permits the Frame Fixation of the storylines in one direction. Consequently, the Frame Fixation direction dictates the grouping structure. Although DDS with separated scenes (shots) require aligned grouping, the analysis of the participants showed they intentionally designed their projects with rich scrolling effects. Lastly, among all the different modalities proposed for DDS, we chose the primary ones (text, image, video, visualization, map) to keep a certain level of expressiveness. Table 3.3 shows the DataStoryDesign adapted language with the considerations and the corresponding symbols.

Symbol	Design Language	DataStoryDesign	Alternative / Considerations
Primary	✓		full support (Modality)
Overlaid	✓		full support
Affixed	✗	no component	Primary
Storyline Foundation	✓	no component	Degree (1, 1) on Grid Canvas
Block Formation	✓	no component	1, 2 Storylines on Grid Canvas
Group Composition	✓	no component	unidirectional (vertical)
Frame Fixation	✓		unidirectional (vertical)
Progression	✓		full support
Transition	✓		full support
Aggregation	✓		full support
Execution	✗	no component	Progression + Interactivity + alternative path
Modality	✓		Text, Image, Visualization Video, Map (Primary and Overlaid)
Expressive Symbols	✓		Effect, Interactivity

Table 3.3 DataStoryDesign adapted by design considerations

### 3.3.2 Features

Other functionalities revolve around the language in Section 3.2 as complimentary features. The range of features for DDS authoring tools in the previous studies varies. The features of DataStoryDesign align purposefully with the core objectives of prototyping DDS. The interface of DataStoryDesign enables users to create and manipulate narrative structures seamlessly. DataStoryDesign users iterate on their storytelling prototypes while discussing the impact of their design choices. It has features such as grid canvas, layouting options, symbols, file management, and parallel and collaborative prototyping capabilities. Among the features, some are still related to the visual aspect of the language, although not directly related. Table 3.4 introduces these features in DataStoryDesign.



*Real-time Environment:* To encourage the collaborative aspect of prototyping and story-

Feature	Type
Real-time Environment	workflow
Auto-save Mechanism	workflow
History Panel	workflow
Commenting Panel	workflow
Overview Panel	workflow
User Panel	workflow
Grid Canvas	visual
Flexible Placeholders	Visual
Text Editor	visual
Bird's-Eye View	visual
Resources Panel	Visual

Table 3.4 The Features in DataStoryDesign

boarding activity, we designed a real-time workflow where the collaborators individually yet simultaneously participate in the story design. All different panels and features in DataStoryDesign are in real-time. Real-time systems remove the burden regarding physical distance requirements for certain activities. However, we don't evaluate this aspect since this study focuses on the design language's applicability. Therefore, we are more interested in knowing the effect of the design language on the prototyping and storyboarding process.

-  *Auto-Save Mechanism:* DataStoryDesign provides live databases that reflect the changes instantly for all the participants. Therefore, no additional step is needed to save the document.
-  *History Panel:* DataStoryDesign archives all steps of visual changes on the canvas. It records the steps counting from the beginning with the ability to retrieve and delete the entire history or part of it. The history panel interactively changes and adjusts the spaces when users change state. The History Panel is shared in real-time for all users with animation to enhance visual communication.
-  *Commenting Panel:* Commenting Panel is another feature that comes with the feature of repositioning the conversation to the visible viewport. The Commenting Panel is multi-thread because every visual element is selectable separately for comment. The user can add, remove, and edit multi-line comments.
-  *Overview Panel:* DataStoryDesign offers an overview window to give more control over accessing, adding, and removing placeholders in a minimized tree structure. This feature is

important because the viewport gets longer as the user adds more elements to the canvas. Therefore DataStoryDesign enables shortcut ways to help the fluidity of the tasks in the workflow.



*User Panel:* DataStoryDesign is a multi user tool. The user panel's goal is to facilitate adding and removing team members in a project.



*Grid Canvas:* The Grid Canvas represents a model that uses parallelism and flexible vertical position alignment. To emphasize the parallel appearance of the visual elements, the placeholders snap to the canvas on highlights cells in the grid structure. In addition, the canvas auto-adjusts the spaces to align elements after adding changes. The canvas supports different alignments for placeholders and supports right-click mouse action for convenience.



*Flexible Placeholders:* Authors fill the content with media files as the prototype progresses. At this point, the wireframe prototypes also play a storyboarding role. To make sure the wireframe prototypes get a closer appearance to the published articles, DataStoryDesign offers different sizing and frame options for placeholders, including fit, auto, and cropped. Single storyline placeholders extend to fit the whole canvas width (full screen) to resemble the full-screen content. These placeholders also support multi-frame content to present stacking placeholders. In addition, these placeholders' height positions are adjustable relative to the longer placeholders. The other features of these placeholders are the ability to render different media formats and show a separable (docked-out) view.



*Text Editor:* Titles and paragraphs are the fundamental elements in every DDS article. DataStoryDesign proposes a text editor to cover preliminary requirements for the typography in structuring DDS.



*Bird's-Eye View:* To enhance the workspace for longer stories, it was necessary to give an all-in-one perspective to users. Bird's-eye view functionality is quick zoom out to the entire story while keeping the canvas responsive and functional in the zoomed-out view.



*Resources Panel:* DataStoryDesign supports various media files, also called resources, in file formats, including images, gifs, videos, and maps. The system for file management archives files separately per project with a total space of 1GB. Adding media files to the placeholders turns a schematic wireframe into a content box with options for sizing using drag and drop. Adding resources to the replica serves a double functionality of prototyping and storyboarding.

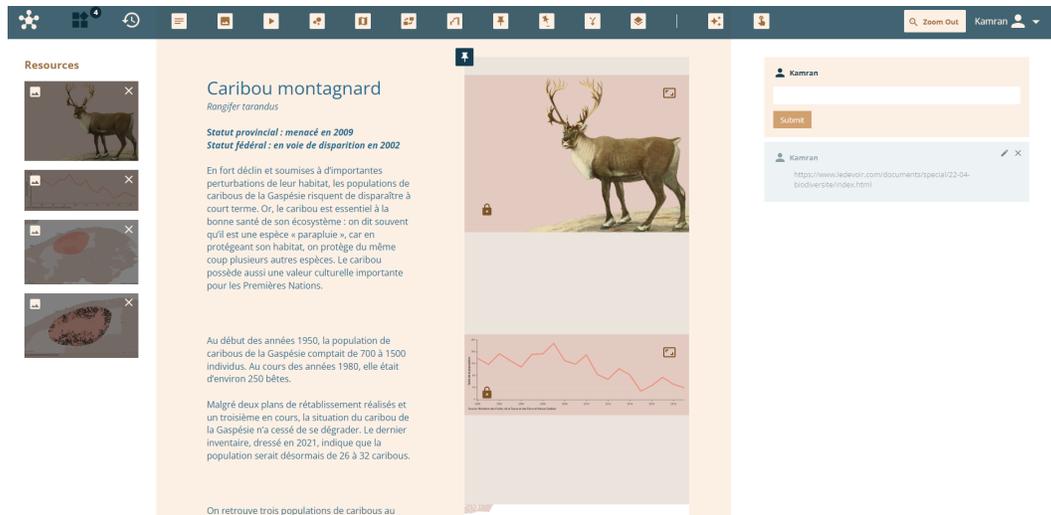


Figure 3.11 A screenshot of a working project in DataStoryDesign

### 3.3.3 Implementation

We designed and implemented our tool as a web application with React.JS backed with real-time database Firebase and Firestore. To work with DataStoryDesign, users used the Google authentication system to log in, create, and access the sessions. All privacy concerns are addressed. The application used encapsulation and inheritance in its skeleton. This architecture in the code specifically helped with some features (history, nested placeholders, overview, and commenting modules).

### 3.3.4 Environment

The workspace of DataStoryDesign is divided into three main sections (Figure 3.11). In the middle section, the canvas exists where users visualize the design language proposed in 3.2. On the right side, there is a fixed commenting panel showing the conversation threads. On the left side, there are three tabs: history, overview, and resources panel, which only show one at a time. The top menu contains the components that represent the design rules of the design language. The main modality icons on the top menu represent the placeholders. Next to them, the Connection (Transition, Progression, Aggregation) and the Frame Fixation (Pin in, Pin out) components take care of all the dynamics between placeholders in the canvas. Continuing the menu, the overlaid placeholder component performs tasks on multiple levels. Finally, two Expressive Symbols define the inner narrative properties of placeholders. On the top right corner, the user panel is accessible through a drop-down menu logged in to the creator's or the collaborator's profile. The bird's eye view icon is on the left side of the side

menu.

### 3.3.5 Interactions

DataStoryDesign embedded UX-friendly animations in two directions. Either to present actions more understanding or hint to the user to notice certain visual elements. These animations are short and simple to enhance visual communication and grab authors' attention. These animations are accessible through the DataStoryDesign GitHub page<sup>1</sup>. DataStoryDesign supports drag-and-drop animated interactions on many components and panels, including the canvas, the placeholder, header components, and the resources. The canvas also highlights potential positions for new items. The canvas supports parallel occurrence by adjusting spaces and connections after changing the placeholder size. Comment threads also support animation by sliding to the parent element. Finally, DataStoryDesign shifts the view to a zoomed-out perspective by running a smooth, slower transition to ensure the user understands the relative portions and the positions of the elements on the canvas. Figure 3.12, 3.13 show another examples of a working project in DataStoryDesign.



Figure 3.12 Another screenshot of a working project in DataStoryDesign

<sup>1</sup>[ikamyx.github.io/DataStoryDesign](https://github.com/ikamyx/DataStoryDesign)

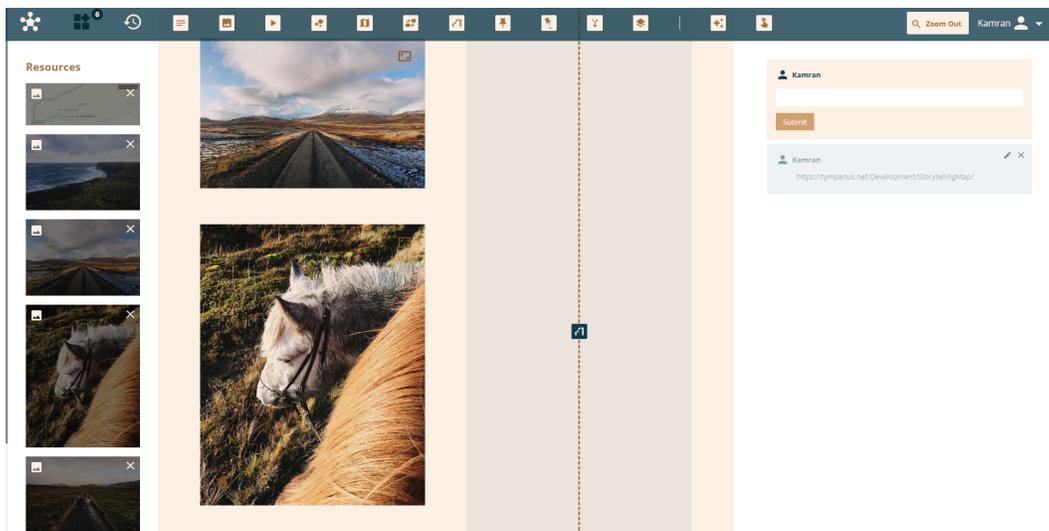


Figure 3.13 Another screenshot of a working project in DataStoryDesign

## CHAPTER 4 EVALUATION

To show the effectiveness of the proposed design language, this study evaluated it in two directions. First, by demonstrating its ability to describe a wide range of DDS. Second, by measuring its usability as a prototyping system in DataStoryDesign. To address the first one, we conducted an audit of 100 published DDS to show the language’s comprehensiveness, versatility, and expressiveness against real-world examples. This audit evaluated the performance and effectiveness of the design language, specifically for more complex forms of DDS. Then, a multi-stage exploratory case study evaluated the language in the production chain of a news agency. This case study first ensured that the participants understood the language’s basic principles. Then, it evaluated DataStoryDesign through a remote pilot experiment in combination with a survey and a group interview.

### 4.1 Audit for 100 DDS

We audited 100 DDS to evaluate different design rules of the design language with real-world examples. We selected 100 DDS since it is higher than the previous studies on this topic [9, 11, 14]. The selection process was convenience sampling from examples of published DDS by notable news agencies and the data visualization community. The inclusion area was choosing the examples that were published in the last five years since web technology accelerated in the previous years. Since DDS development is heavily dependent on web limitations, our DDS selection includes the recent changes in web standards. We also ensured we included a different range of DDS types including layouts, path structures (linear, non-linear), arrangements, and interactivity. However, this doesn’t prevent us from diversifying the selection.

We started the audit process by prototyping the 100 DDS selection with the design rules provided by the language. This process allowed us to break down the structure of our DDS selection. The result of this audit process is available on Google Sheets<sup>1</sup> in a tabular format. The result shows the performance of our proposed design language against the 100 DDS selection. The first and second fixed rows present a checklist (4.1) that includes the design rules and some extra information we collected about each DDS. The number in the Block Formation (Degree of Block) represents the number of storylines per block. The pair number in the Storyline Foundation (Degree of Division) shows the number of crossing Overlaid Placeholders. The audit provides information on the applied principles and shows which

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<sup>1</sup>[ikamyx.github.io/DataStoryDesign/audit](https://ikamyx.github.io/DataStoryDesign/audit)

types of placeholders (primary, overlaid, affixed) are targeted by these principles. The audit also provides a separate link to each DDS available by the time of authoring this manuscript. In the case of existing multiple paths for certain DDS, all the variations are included in the spreadsheet. The audit put the frequency rate of each design principle at the bottom row of the spreadsheet. The audit also calculated the result by accumulating different types of placeholders (Primary, Overlaid, Affixed) for each principle. Since there are examples of nonlinear DDS in our DDS selection, we put multiple versions of some DDS. In the calculation process, we counted each single DDS one time exclusively. Our audit put the result of this calculation at the bottom of the spreadsheet.

#### 4.1.1 Result and Analysis

We define the *comprehensiveness* of our design language as its ability to cover all the necessary design rules for defining a visual structure of DDS. In other words, our design language is comprehensive if we redefine and replicate the narrative structure of DDS selection by its rules. These design rules remodel aspects like layouting, positioning, animations, and content into a DDS replica. Through the audit result, we replicated DDS selections with the design rules of the proposed design language. Therefore, this audit process reveals that the design language is entirely comprehensive within the range of the DDS selection. The result suggests that this model of representing DDS is effective since it can remodel more complex forms of DDS. Among the 100 DDS selections, there are highly interactive examples of DDS that take a lot of resources to create. These types of DDS were not discussed and analyzed in detail in the previous studies. Our proposed design language, however, gives flexibility in design to a certain extent. In some cases, authors have different solutions to present a scene, e.g., as one grouped placeholder vs. parallel storylines. Therefore, for this audit process, we inspected the roles of DDS elements based on the semantic meaning of each element to get the most accurate result.

We define *versatility* of the design language as the ability to support a wide range of narrative structures and design elements. It indicates that the DDS selection is diverse in its narrative structure, as shown in Figure 4.2. Some stories exhibit a linear progression with a single storyline, while others showcase more complexity with multiple storylines, grouped overlaid elements, and transitions. This diversity indicates that the design language effectively represents different narrative approaches, accommodating straightforward and intricate storytelling styles. Figure 4.2 shows an example of this diversity in our DDS selection. In addition, Figure 4.3 reflects the accumulated frequency percentage of the audit checklist.

The graph in Figure 4.2 skips the fundamental design rules like Storyline Foundation and



Expressiveness	Modality				
	P	O	A		
	Expressive Symbols				
	P	O	A		
Replication	Placeholders				
	P	O	A	S	F
	Stacking				
	P	O	A		
	Affixing				
	P	O			
Narration	Storyline Foundation				
	1	2		3	
	Block Formation				
	(1, 1)	(1, 2)		(2, 1)	
	Group Composition				
	P	O			
	Frame Fixation				
	P	O	A	Grouped P	Grouped O
Connection	Progression				
	P	O	A		
	Transition				
	P	O	A		
	Aggregation				
	P	O	A		
	Execution				
P	O	A			

Table 4.1 Audit checklist: Placeholders including (P)primary, (O)overlaid, (A)ffixed, (S)tacked, (F)ull-screen

Block Formation since they are necessary to create all DDS examples. Therefore, their frequency rate is always %100. The graph shows the popularity of Frame Fixation and Progression among the DDS selection. This graph explains why participants in the brainstorming sessions indicated that they mostly use scrolling effects in their DDS projects. In addition, the audit result inspected more details on DDS layouts derived from the design principles, e.g., full-screen layouts (derived from Primary Placeholders). The full-screen layouts showed a significant frequency rate of %45.

We define the *expressiveness* of our design language as its ability to showcase the behavior of the content of the original versions of DDS (Modality and Expressive Symbols). Furthermore, we captured a wide range of modality choices and expressive symbols employed in the DDS selection through the audit process. These included text, visualization, image, video, data, data video, input, and map. It demonstrates the language’s ability to accommodate diverse content types and present the storytelling structure through various modalities. Figure 4.4 projects various modalities in DDS selections, except for text that appeared in all audit entries. Data videos and videos (excluding data footage) collectively appeared in more than one-third of the entries. This result means that regardless of DDS interactions, video use case is significant. While some combine videos with interaction to give the audience more control, many prefer auto-playing videos. Regarding Expressive Symbols, most DDS entries use interaction and effect on different visual elements. These interactions are different than

If you want to know how many rolls you need for a different number of days, just multiply the per day average by the numbers of days you want.

Of course, the better your estimates on the sliders, the better the estimate for the total roll count will be. To test this out, I started paying closer attention to usage in my own household and I was surprised by the number of squares on each wipe and number of wipes total.



The wide variation of toilet paper roll sizes was also surprising.

A standard roll from Costco has 425 sheets. But if you get that Ultra Comfort Care from Cottonelle, you only get 121 sheets. Unless you get Mega roll, in which case you get 284 sheets. Going the other direction, the single ply toilet paper has 1,000 sheets per roll (although you probably end up

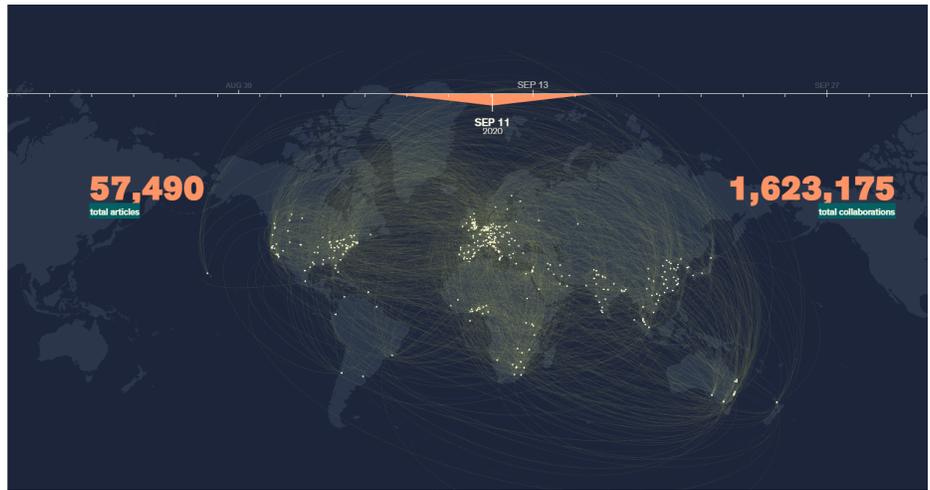


Figure 4.2 Simple DDS for creating wireframe versus complex DDS creating wireframe

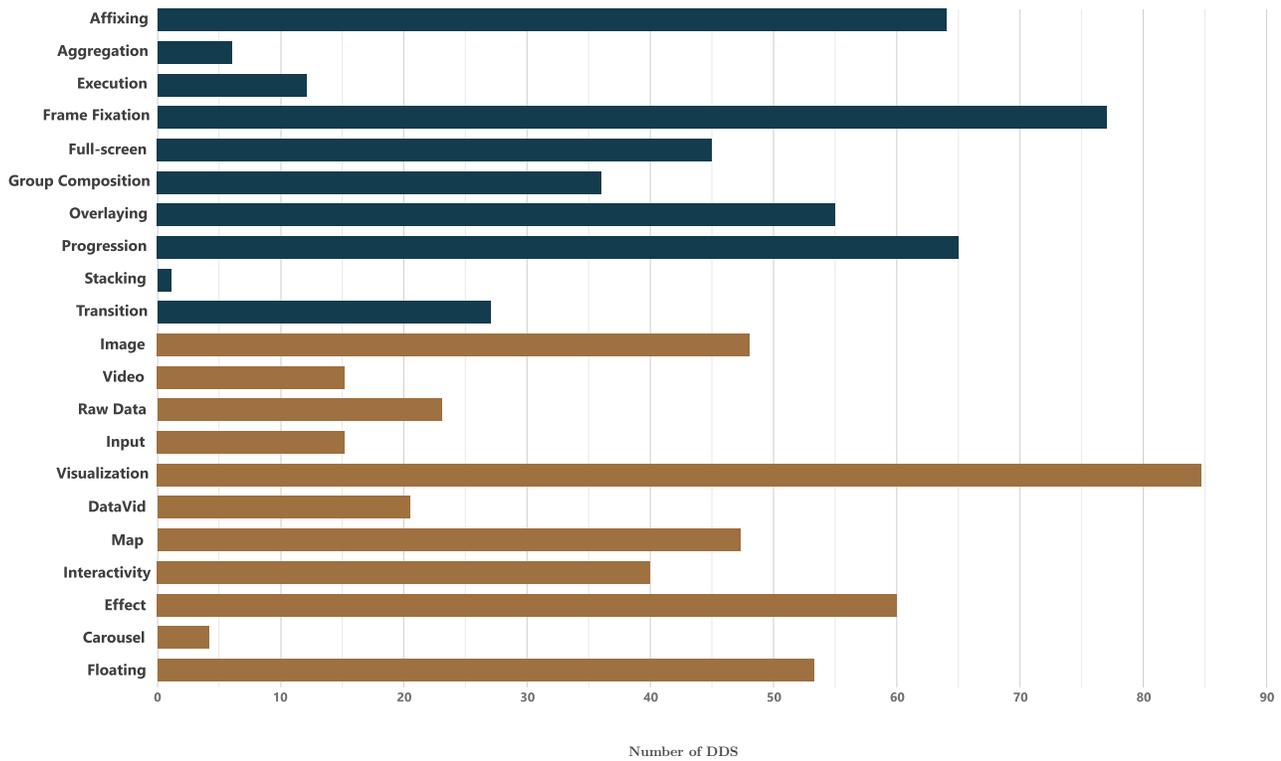


Figure 4.3 Design rules frequency in 100 DDS selection

DDS progression through scrolling effects or Frame Fixation. Since these interactions target the interactivity of individual placeholders, it is different from story Progression effects via scrolling. Figure 4.5 shows the audit result.

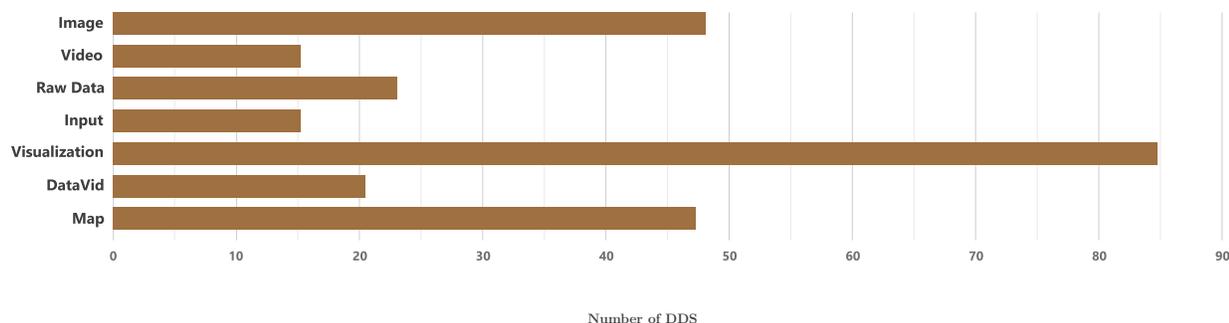


Figure 4.4 Expressiveness (Modality) rules frequency in 100 DDS selection

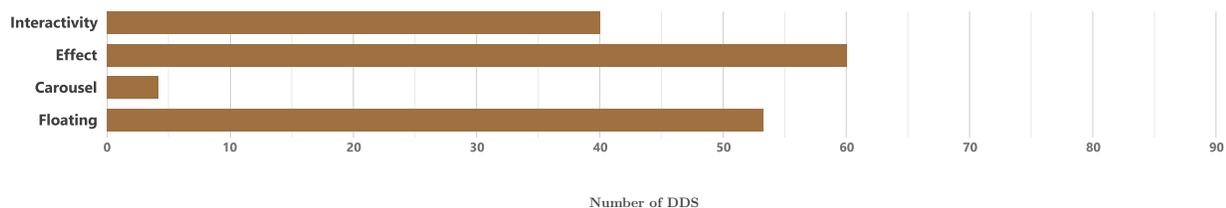


Figure 4.5 Expressiveness (Expressive Symbols) rules frequency in 100 DDS selection

The audit process also confirms the DataStoryDesign requirements obtained through the brainstorming session, like Block Formation and Storyline Foundation. The result reveals that the stories are less likely to simultaneously use more than two storylines. They also show that when Frame Fixation and Overlaying happen, authors prefer to keep one specific narrative element in their design to keep the audience's attention. This behavior explains the frequency rate of the Degree of Division (1, 1) in the audit result. However, because of the expressiveness in the design language, under the same settings as DataStoryDesign, authors can combine different design rules with various modalities and symbols to construct the narrative structure.

## 4.2 Prototyping and Storyboarding System Evaluation with DataStoryDesign

To evaluate the prototyping and storyboarding aspects of the design language, we designed a multi-step exploratory case study consisting of a remote pilot experiment with DataStoryDesign accompanied by introductory templates, surveys, and a group interview with

participants. The multi-step exploratory case study aims to demonstrate the initial effectiveness of DataStoryDesign in a real-time environment of DDS production, particularly within an actual production chain workflow involving industry professionals. This study aims to provide valuable insights into how DataStoryDesign, integrated with the design language, impacts the efficiency, collaboration, and narrative structure of DDS production. This case study highlights the practical applicability and early indicators of success in utilizing DataStoryDesign for enhancing the DDS production process within an industry context.

As the core of this evaluation, the remote pilot experiment let the participants openly access DataStoryDesign and its prototyping and storyboarding system using the design language introduced in Section 3.2. The idea behind this is to remotely observe the project information of the participants during the experiment. The information is all driven by the participants' decisions, interactions, and history logs stored in the experiment. Our collaborator news agency introduced us to six participants ( $N = 6$ ) who had a role in DDS production. One of the participants (designer role) was the same person who contributed to our brainstorming sessions (3). The role of the participants varied from media director (non-technical) and journalist (non-technical) to motion designer and designer (semi-technical) and front-end developer (technical). In addition, the range of years of experience of participants varied from one year to fifteen years.

As the brainstorming sessions enlightened the participants' expectations, they (U1-U6) were provided with introductory information to DataStoryDesign and its functionalities. We onboarded the team by adding team members and including project media files. We asked the team to use DataStoryDesign for two weeks as a prototyping device for their upcoming projects collaboratively and simultaneously. We asked them to create parallel projects and use the projects' media content. We explained the setting according to the requirements while showing the tool interface. We did not enforce any specific workflow or design strategy in DataStoryDesign to avoid users' biases throughout the process. In addition, we included six implemented replicas from the audit DDS selection as pre-saved projects. Since their final version had been published, participants could explore the design rules through these project files.

To get more first-hand feedback after the pilot experiment, we arranged individual surveys<sup>2</sup> on participants (U1-U6) designed with Google Forms in five parts: the design language in DataStoryDesign, prototyping and storyboarding with DataStoryDesign, user experience, visual communication, and summary. The survey consists of open-ended and close-ended questions about these parts' effectiveness and quality. The survey was purposefully designed

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<sup>2</sup>The questions of the survey are available in the Appendix Section

as complementary information to the remote pilot experiment results to explain how this DataStoryDesign shaped the participants' experience.

We then conducted a group online interview with the participants (U1-U6). This group interview focused more on collaborative aspects and individual and group challenges with DataStoryDesign. We aimed to discover more details about the prototyping process using the design language, including its strengths and limitations. This phase aimed to discover more details on prototyping using the design language, its strengths, and limitations. We interviewed participants through Zoom video conference for an hour. The interview questions weren't scripted to keep the conversation open for the participants. Through the interview, we asked the team to demonstrate their workflow to ensure they understood each design rule's functionality.

### **4.2.1 Result and Analysis**

#### **Remote Pilot Experiment**

For the analysis process, we implemented a custom function inside DataStoryDesign to collect users' activities (individual and collective) by reconstructing an extended history. This derived function duplicates every state with extra information like timestamp, mouse action associated with (click, right-click, drag and drop), and affecting component (feature). By analyzing this information, we extracted the number of appearances for each design rule used in the final design versus the number of reverted attempts in history. Figure 4.6 shows this comparison.

The graph of Figure 4.6 does not include Block Formation, Storyline Foundation, and Modality since these principles build Placeholders, Storylines, and Blocks. These elements appear in every DDS regardless of genre and complexity. The graph projects the result of seven projects in the remote pilot experiment. The participants added thirty-seven (37) media files to these projects. In addition, the participants used all implemented modalities in their replica, including text, image, video, map, and visualizations.

#### **Survey**

We ran an individual survey after the remote pilot experiment on the participants (U1-U6). We targeted multiple criteria through this survey to better understand the design decisions during the remote pilot experiment (the design language in DataStoryDesign, prototyping and storyboarding with DataStoryDesign, user experience, visual communication, and summary). The answers reveal %75 of the participants had tried prototyping and storyboarding for DDS

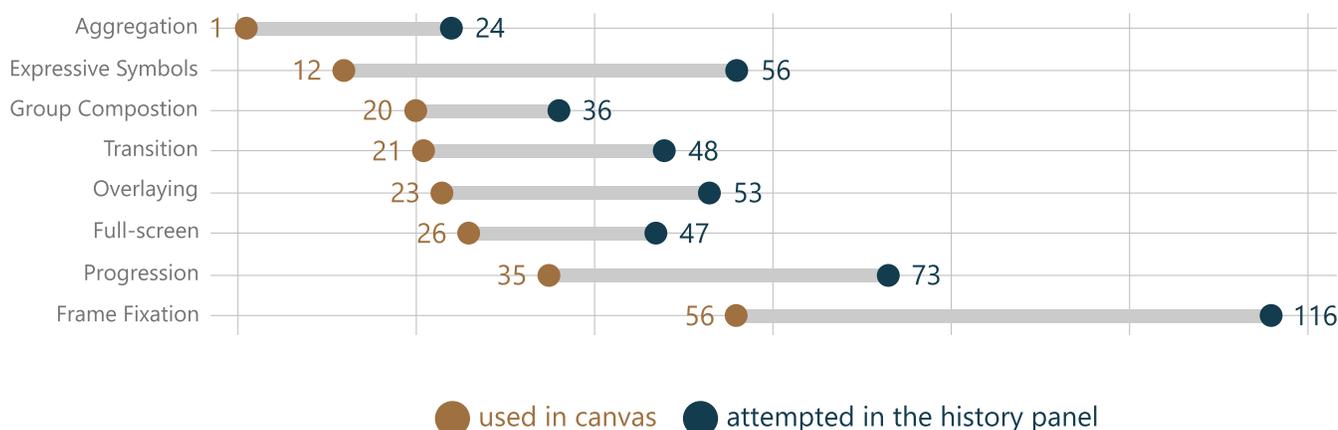


Figure 4.6 The frequency comparison of the design rules

production before trying DataStoryDesign. The participants added that the prototyping and storyboarding system of DataStoryDesign were effective in their workflow by %80. The participants mainly defined their goal from prototyping and storyboarding as a *"planning phase before implementation"* as well as *"accelerating idea generation"*. Figure 4.7 shows the overall experience score (1 - 5) for the design language versus prototyping and storyboarding with DataStoryDesign.

The survey result shows that the participants' overall experience with the design language and its prototyping and storyboarding application is effective. However, in the open-ended questions, the participants acknowledged the possible improvements to replace their workflow with DataStoryDesign. U3 suggested that they need functionality to let them preview an early version of the output while their structure progresses. In addition, U1 mentioned they do not necessarily use the real-time functionality all the time since their team size is not big. The participants also wrote that this visual method of representing DDS is effective for visual communication, although there is room for improvement. On the negative side, two participants (U2 and U4) reported bugs in formatting text. U2 described using resources tools to replace media files one by one into the placeholders as inefficient.

### Group Interview

During the group interview, participants provided detailed insights about the design language and the prototyping and storyboarding experience with DataStoryDesign. The group interview aligned with the survey results and confirmed the effectiveness of the design language and its application in DDS prototyping and storyboarding through DataStoryDesign. While the overall feedback was positive, participants identified areas for improvement. U1 and U2

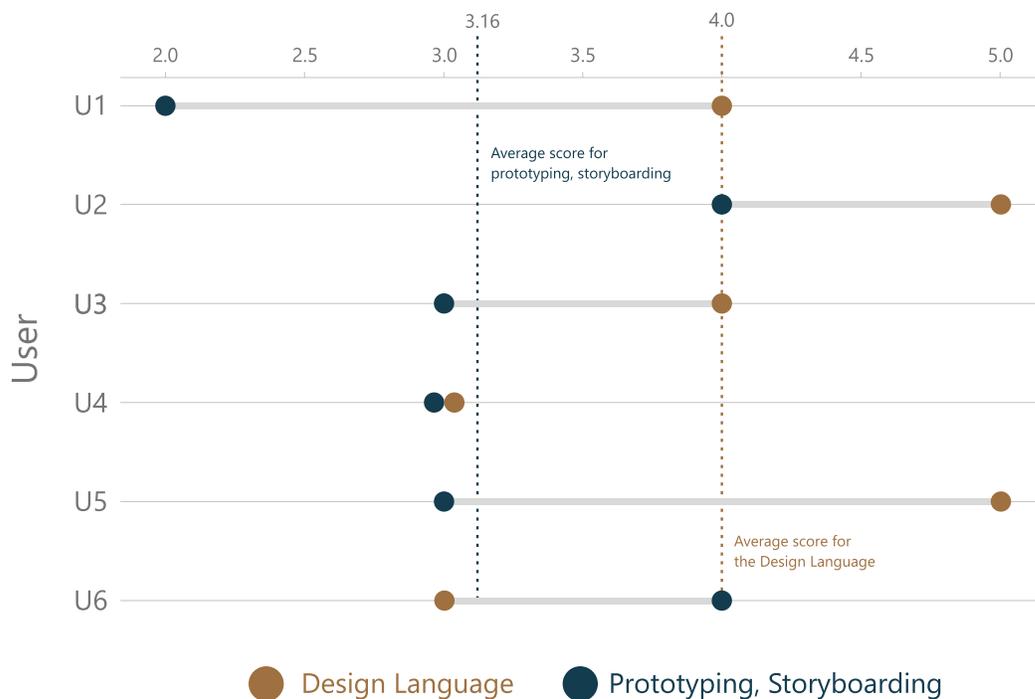


Figure 4.7 Survey result (Overall experience score (1 - 5) of the design language vs. prototyping and storyboarding with DataStoryDesign)

suggested a preview button to visualize early output versions, enhancing the prototyping experience. The participants described the benefit of history as an archive of all design decisions in their workflow. U3 emphasized the need for better responsiveness and docking functionality to manage windows alongside the canvas. Participants also desired more flexibility, drag-and-drop features, bulk photo adding, and options to hide sidebars. U1 mentioned the usefulness of the Bird's-Eye View, which improves visual communication by showing an all-in-one preview. U3, as a journalist, however, indicated that the text formatting in the prototyping process was not satisfying.

Regarding the design language, participants highlighted the benefits of it as a core structure for prototyping and storyboarding, with U1 mentioning that building different layout options is possible. U2 and U4 emphasized the importance of canvas and the snapping grid system, where they can easily position new placeholders. This grid system combines parallelism, the Storyline Foundation, and the Block Formation design rules. We followed the interview by asking questions about the design rules the team missed or misused. Most participants doubt using Expressive Symbols since they prefer to replace content as the design progresses. In addition, most participants said more language flexibility in Block Formation, Storyline Foundation, and Group Composition will not confuse them as long as proper onboarding

sessions are being provided. In the end, the participants indicated that using the design language improved the overall visual communication in their DDS production workflow. The participants were satisfied with prototyping and storyboarding using the design language, anticipating further development of the design language, prototyping, and storyboarding with DataStoryDesign. The practical application of the design language and the accompanying tool, DataStoryDesign, was exemplified through various user experiences that shed light on its effectiveness. According to U1, "The design language made exploring different layout options feasible with a structured approach that allowed me to experiment with various visual arrangements." U2 elaborated, "The canvas and the snapping grid system were effective and allowed me to position placeholders easily and maintain consistency in the layout." This sentiment was echoed by U4, who noted, "The grid system, combining parallelism, the Storyline Foundation, and the Block Formation design rules, provided a solid foundation to visualize the overall narrative structure."

Moreover, the Bird's-Eye View feature received acclaim from U1, who said, "The Bird's-Eye View was an interesting feature. Being able to preview the entire narrative layout at a glance improved the cohesion of the story." U3, a journalist, emphasized the impact on their workflow, sharing, "Using the design language significantly improved the overall visual communication in our DDS production process. It streamlined collaboration and ensured a clearer understanding of the narrative flow."

These firsthand accounts underscored the practicality and efficacy of the design language and its integration into DataStoryDesign. Participants expressed satisfaction with the newfound ease and effectiveness of prototyping and storyboarding, highlighting the potential for further refinement and development in this innovative approach. The participants' positive experiences and constructive feedback further validate the contributions of this research in enhancing DDS production workflows.

### **4.3 Conclusion**

The evaluation of the design language reveals that it is comprehensive, versatile, and expressive to support various types of DDS. The language's adaptability to various narrative structures was evident through an extensive audit process and analysis of 100 DDS examples.

In addition, the preliminary results of the exploratory case study indicate that DataStoryDesign, as the prototyping and the storyboarding system for this design language, is effective in DDS production workflow. The preliminary results indicate that using a design language in the design process improves visual communication, letting DDS authors try more alternative

design solutions.

Regarding the goal of the multi-stage exploratory case study, we achieved our objectives by showing the practicality of DataStoryDesign within the workflow of industry professionals. The use case of the design rules in their project accompanying their projections into surveys reflected meaningful insights on the prototyping and storyboarding experience and the limitations of such a system. We conclude that using a design language for story design purposes is promising to be acquired in a broader spectrum in DDS production.

## CHAPTER 5 DISCUSSION

In the previous Chapters, we explore the development of a design language aimed at improving the prototyping and storyboarding processes for DDS. Our focus was on enhancing the narrative structure of DDS narratives, leading to several benefits for authors and the storytelling workflow. The design language allowed authors to explore alternative story designs while maintaining coherence in the narrative structure. Additionally, prototyping the DDS narrative structure became more accessible and efficient by integrating this language, enabling authors to bring their ideas to life quickly. Storyboarding was also streamlined, promoting more collaboration among DDS authors involved in DDS production. Moreover, the design language facilitated enhanced visual communication, aiming to enhance future DDS authoring tools and related studies. In this Chapter, we first discuss key differences between design solutions for DDS narrative structure from previous studies and tools with our design language. We then discuss some design language interpretations and implications, exploring its potential contributions to the DDS production workflow.

### 5.1 Design Language Differences with Similar Studies and Tools

A distinctive feature that sets our design language apart from existing studies is the unification of different visual aspects of DDS into a single coherent structure from a holistic perspective. In contrast, previous research predominantly concentrated on dissecting individual elements of DDS, such as path structures, transitions, and layout, without achieving an integrated approach. Notably absent in prior works is the division of macro and micro structures, along with inner-narrative components, into one holistic framework, which our design language successfully achieves. Furthermore, we take a step by embedding the definition of DDS structure within the context of storyboarding and prototyping, a dimension overlooked mainly in previous investigations.

Additionally, our design language distinguishes itself by its practical orientation in the early design stages. While other models and visual solutions primarily cater to the exploration needs of DDS researchers and professionals, our language is a practical tool for authors to experiment with their narrative designs. This tangible application sets our work apart regarding practicality and real-world implementation. In contrast, many existing studies offer descriptive models, such as narrative patterns, that provide conceptual insights but lack practical solutions for DDS creators. This practical focus further underscores the uniqueness of our design language in addressing the complex challenges of DDS narrative structuring.

A fundamental disparity lies between the structure offered for DDS narrative in current authoring tools, prototyping, and storyboarding solutions compared to our design language. Most prevailing tools provide limited options for testing alternative design solutions, often constrained by predetermined templates and layouts. In contrast, our design language emphasizes the flexibility to show variations of story designs, focusing on coherence and readability across various personas involved in DDS production. This adaptability bridges the gap between different personas and their perspectives on narrative structure.

Furthermore, our design language excels in the domain of rapid prototyping, a functionality often absent in existing prototyping tools. The prevalent tools lack scaffolding and wireframe structures essential for constructing intricate DDS narratives. In contrast, our language streamlines the prototyping process, offering a well-structured foundation for DDS production.

Additionally, our design language stands out since it functions effectively even when content and charts are under development. While certain features, like the preview function, might position it alongside publishing-oriented DDS tools, our language remains versatile and adaptable to the evolving nature of DDS production. This unique trait enables DDS authors to engage with the narrative structure at any stage, fostering enhanced visual communication and more efficient workflows.

## 5.2 Investigation on Highly Interactive DDS Structure

As a result of combining the design rules with DDS elements, more complicated layout forms are interpretable. These layouts are divisible to a set of rules using multiple design rules simultaneously. The design rules of the design language combine the layouts, positioning, and timing of all role-playing visual elements in DDS. Therefore, the study demonstrates the high flexibility of the model by visualizing more complex layouts. Our design language is producing the following illustrations. These structures have been ranked by difficulty based on the investigation of DDS layouts through our initial assessments in the audit process. This list only showcases only some of these DDS forms.

The simplest of these layouts that DDS authors overlook is using long visualizations. This type of narrative structure hasn't been addressed in any current DDS authoring, prototyping, and storyboarding solutions. By using a single Storyline (Block Formation,  $n = 1$ ) and short fixated area (Frame Fixation) of separately connected placeholders (Connection), we can demonstrate such a narrative representation. This comparison between (a) and (b) shows how, in the early stages of prototyping and storyboarding, (a) will fulfill the communication

goals compared to (b). Figure 5.2, on the left side, demonstrates this layout structure. The implications of such a structure appeared in our audit process. Fig 5.2, on the right side, shows this use case.

In another form of layouts, in a double Storylines setting (Block Formation,  $n = 2$ ), one Storyline contains various crossing elements, while the other gradually changes. Sometimes, we stage complex transitions into multiple frames without being concerned about sacrificing visual communication. Figure 5.2, on the left side, shows this narrative structure. Additionally, sometimes an Overlaid placeholder gets fixed to the viewport, letting other elements cross behind. While this happened on multiple examples in the audit process, the Primary placeholder gets the floating symbol. While other DDS narrative structures fail to visualize these dynamics, the implications of these two scenarios are significant.

Despite the fact that our design language shows promising results in the audit process, it doesn't mean it covers every DDS. Our initial assessment suggests that the design language may need future adjustments. For example, if elements cumulatively become fixated to the viewport, we need a mechanism to indicate the order of elements divergence. In addition, online gaming has increasingly pervaded various industries, including journalism. Our language may not be suitable for conveying a 3D. Figure 5.3 shows an untested solution we came up with for multiple elements in Frame Fixation.

Overall, researchers may benefit from expanding the design language, especially if it involves active participation from news industry professionals in the design process. By incorporating their valuable experience and insights, the design language can effectively address the practical challenges encountered during real-world DDS production workflows. This collaborative approach can help identify and overcome potential pitfalls, ensuring the design language remains relevant and applicable in actual DDS creation scenarios. As a result, the design language can evolve to serve the authors' needs better and improve the overall effectiveness of prototyping and storyboarding processes in DDS production. However, it is essential to acknowledge that the success of the design language may also rely on continuous feedback and iteration from diverse stakeholders to enhance its usability and applicability across various newsroom scenarios.

Furthermore, as our participants suggested in the interview, the integration of real-time preview functionality leads to showcasing immediate results of the prototyping process. This functionality can elevate the prototyping experience to an entirely new level. This feature can enhance the efficiency and effectiveness of the prototyping process, enabling researchers and DDS authors to visualize and evaluate their design decisions more intuitively. While the realization of this advanced level of prototyping may be an ongoing journey, it is evident

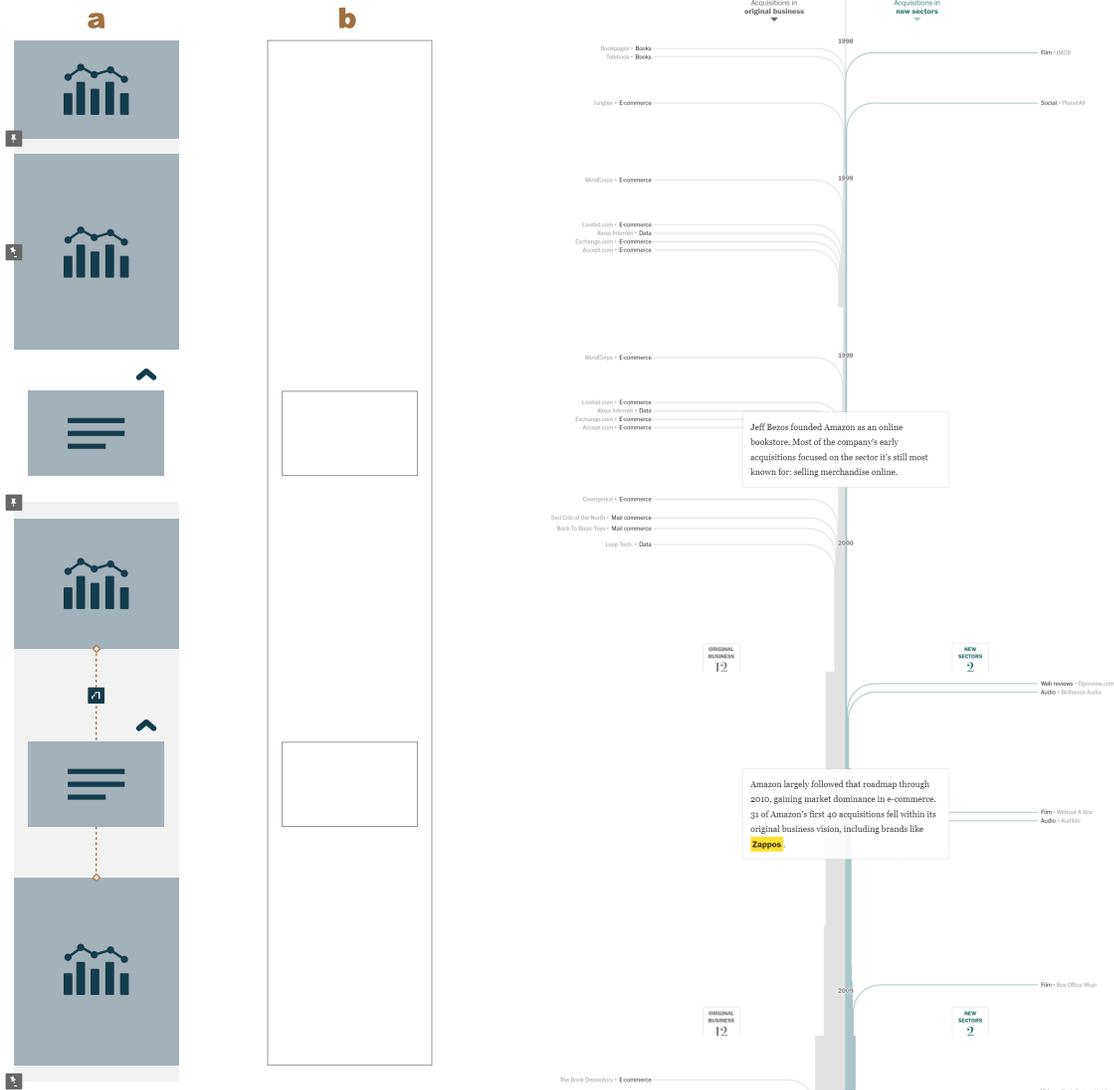


Figure 5.1 Left: Long placeholder: (a) Design language version of the narrative structure, (b) Approximate positioning of the content, Right: A single Storyline with a long placeholder, taken from washingtonpost.com



Figure 5.2 Left: A representation of a slow and gradual staging in DDS narrative structure, Right: An Overlaid placeholder gets fixed to the viewport after sliding over, changing to another form while the Primary placeholder crosses behind it.



Figure 5.3 Untested design solution for diverging elements in Frame Fixation, (a, b) Using line separator, (b) darker background, and (a, b) tags on placeholders to identify the divergence order

that researchers and industry professionals will inevitably explore and adopt such innovative approaches to refine further and streamline the DDS production workflow.

## CHAPTER 6 CONCLUSION

In this Chapter, we summarize our proposed design language, the prototyping and storyboarding system, DataStoryDesign. We mention the limitations and future research prospects for it.

### 6.1 Summary

We proposed a design language for the DDS narrative structure through this work. The process of developing this language contained three steps that used the deductive coding approach to help us in the thinking process of developing the design language and DataStoryDesign as the prototyping and storyboarding system for it. First, we started by extracting insights about the DDS narrative structure as tags (codes) from a thorough top-down review of the previous literature on this topic. Second, we conducted a series of brainstorming sessions with the news industry professionals to ensure the tags obtained from the insights of the first step are applicable in real-world scenarios of DDS production. For the last step, we finalized the deductive coding process by structuring the tags (codes) into different groups: (Goal, Compatibility, Basis, Arrangement, Transition, and Scene). These steps facilitated the thinking process before the development of the design language. In addition, we used the brainstorming information to investigate further the DDS producers' requirements to develop a prototyping and storyboarding system for it. Our proposed design language comes into four categories: (Expression, Replication, Narration, and Connection). Each dimension further breaks down into smaller design rules. These dimensions overall create a comprehensive and integrated structure for the DDS narrative. Expression refers to the expressiveness of the contents of DDS. Replication refers to the position of the related content. Narration refers to the overall arrangement of the contents. Connection refers to the changes happening between contents in DDS. The preliminary result of the evaluation of this design language reveals that it is comprehensive, versatile, and expressive, effectively supporting a wide range of DDS. Furthermore, the evaluation suggests that the capabilities of DataStoryDesign are effective regarding the prototyping and the storyboarding of the DDS production workflow. Utilizing this design language in the creative process enhances visual communication and empowers DDS producers to explore various alternative design solutions. These findings underscore the potential of DataStoryDesign as a valuable tool for facilitating DDS production workflow.

## 6.2 Limitations

We count the limitations of our proposed research as follows:

- The information gathered during the brainstorming sessions before the development of DataStoryDesign lacks any focus on the UX aspects of prototyping and storyboarding. As a result, we don't consider the development process of DataStoryDesign fully user-centered. The design language employed for prototyping and storyboarding in DataStoryDesign introduces specific visual requirements that may overlap or conflict with UX-centered design strategies. The UX actions related to design rules became complicated in some cases. For example, for performing the Frame Fixation design rule, the participants use only two components (pinning in and pinning out) to perform three tasks (start a fixated area, finish a fixated area, remove a fixated area). Therefore, they need to learn the UX-related action for all of them. The previous studies on DDS have not yet explored the specific UX requirements of the prototyping and storyboarding process in DDS. Among these studies, only Walker et al. suggest general guidelines for storyboarding in visual analytics, which has a broader spectrum. Since UX design is a complex topic to convey, involving the UX-related requirements in the design process of our prototyping and storyboarding system needs a thorough investigation of different directions of this topic. This challenging limitation exists both before the development of the system and in the evaluation phase.
- The insights collected during the brainstorming session were limited since we obtained this information from a few industry professionals and newsrooms. Although this information was valuable and helpful in developing our design language, it will not reflect everything happening in the news industry. To better understand DDS production workflow and its requirements, we need to widen our information source by involving more personas from more newsrooms.

## 6.3 Future Works

Future works could explore integrating the design language developed in this proposed work into existing DDS authoring tools, storyboarding, and prototyping systems. Adapting the design language to these tools could enhance the efficiency and effectiveness of the DDS production workflow, allowing authors to create more diverse and engaging DDS. Additionally, further research could focus on user-centered design strategies for DDS authoring tools. By incorporating UX aspects into the design process, future systems could provide more intuitive

and user-friendly interfaces, making it easier for authors to create compelling narratives with data.

Furthermore, we found examples like highly immersive 3D DDS that may be a future industry direction. A thorough work can expand the design language and its applicability in the prototyping and storyboarding process. We mention that such a flexible language, prototyping, and storyboarding system needs well-thought-out planning for DDS producers' onboarding process. Moreover, future studies could investigate the impact of the design language on the audience's visual communication and understanding of DDS narratives. Understanding how the design language affects audience engagement and comprehension could provide valuable insights for optimizing the storytelling process. Furthermore, exploring the potential of the design language beyond DDS could be an exciting avenue for future research. The principles and guidelines developed in this work could be adapted and applied to other forms of data visualization and storytelling, broadening the scope and impact of the design language. Finally, continuous collaboration with media outlets and news publishers could further validate and refine the design language based on real-world use cases and feedback from professionals in the field. This iterative approach to improvement and refinement could lead to a more robust and widely adopted design language for DDS and online journalism in general.

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## APPENDIX A SURVEY QUESTIONS

### Part 1) The Design Language

- On a scale of 1 to 5, How was your experience regarding adding different types of placeholders (Visualization, text, image, video, map)?  
Please elaborate. . .
- On a scale of 1 to 5, How much were you able to emulate the transitions?  
If your experience was unsuccessful please elaborate. . .
- On a scale of 1 to 5, How much were you able to emulate the scrolling effect (fixed columns)?  
If your experience was unsuccessful please elaborate. . .
- On a scale of 1 to 5, How much were you able to express the animations and effects?  
If your experience was unsuccessful please elaborate. . .

### Part 2) Storyboarding and Prototyping

- On a scale of 1 to 5, How effectively could you storyboard and prototype your desired project?  
If your experience was unsuccessful please elaborate. . .
- On a scale of 1 to 5, How much Were you able to emulate your desired layout with DataStoryDesign?  
If your experience was unsuccessful please elaborate. . .

### Part 3) User Experience

- On a scale of 1 to 5, How was your experience regarding creating, saving, and accessing sessions?  
Please elaborate. . .
- On a scale of 1 to 5, How was your experience accessing your media files?  
Please elaborate. . .

- On a scale of 1 to 5, How was your experience regarding undoing changes (history)?  
Please elaborate...
- On a scale of 1 to 5, How was your experience with commenting?  
Please elaborate...
- On a scale of 1 to 5, How was your experience regarding overlaying the menu on placeholders?  
Please elaborate...

#### Part 4) Visual Communication

- On a scale of 1 to 5, How was your communication with your other team members?  
Please elaborate...
- On a scale of 1 to 5, How much did you have to explain your design decisions to your team members?  
Please elaborate...

#### Part 5) Summary

- On a scale of 1 to 5, In total, How much did DataStoryDesign contribute to your DDS production?  
Please elaborate...
- On a scale of 1 to 5, In total, How much the design language for the DDS narrative structure was effective in your workflow?  
Please elaborate...
- Please write other issues and your suggestions for future improvements...