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The aim of this report is to provide an overview of existing narrative visualization and "data-driven storytelling" solutions developed specifically for communicating memories of Nazi persecution. We classify related work based on a taxonomy for visualization-based storytelling for cultural heritage, focus on design dimensions that have not yet been discussed thoroughly, and outline future challenges, some of which are addressed in MEMORISE.

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Introduction

Witnesses of important historical events fade with time, and the urgency to capture their testimonies and experiences for future generations thus becomes increasingly important. In this context, cultural heritage institutions are faced with the task of not only preserving these invaluable memories but also conveying them in a manner that resonates with contemporary audiences. As the media landscape undergoes rapid transformations, innovative strategies become vital in ensuring these preserved memories remain accessible and relevant to a broad audience. Data-driven or narrative storytelling, recently unified under the term 'visualization-based storytelling' (VBS) by Kusnick et al. (Kusnick et al., 2023), embodies a storytelling approach that combines narrative with visual information design. VBS is a promising avenue that has demonstrated the potential in bringing diverse historical narratives to life. Drawing upon current research and development in this area, we conduct a state-of-the-art survey on storytelling, focusing specifically on narrative storytelling for cultural heritage sites with a focus on the Heritage of Nazi Persecution (HNP). We build upon prior work by Kusnick et al. (Kusnick et al., 2023), which assemble a robust design space of storytelling design choices specifically assembled for the digital humanities and cultural heritage domain. As our project requires an adaptation and extension of this design space, we orient it towards cultural heritage sites and tailor it around the narration of historical events, such as the Holocaust. In adapting the design space proposed by Kusnick et al. (Kusnick et al., 2023), we discard specific dimensions and incorporate and interweave new categories and sub-categories. The addition of new categories or removal of existing ones is based on the analysis of a refined list of storytelling examples and related works focusing on storytelling for cultural heritage sites with a focus on HNP. Ultimately, this work allows us to identify trends, possible gaps, and missed opportunities in technology-driven projects in various areas of historical remembrance and digital heritage.

Structure of the survey

We define the premise for our work from the challenges and opportunities in regard to VBS for cultural heritage sites with a focus on HNP. From this premise, we researched which methods have been used in prior work to create a basis for our analysis. The methodology used in our data collection was focused on uncovering certain trends and tendencies of current cultural heritage sites. From the survey we then identified specific markers correlating with the existing design space created by (Kusnick et al., 2023). By analysing the individual examples, we then defined areas in the design space that could benefit from subcategories specified for cultural heritage sites with a focus on HNP and created new dimensions in an extended design space. These findings create the basis for further discussion about the common trends in VBS and how to utilize these elements on cultural heritage sites.

Background

Preserving and disseminating the stories of tangible and intangible assets linked to cultural heritage sites with a focus on HNP presents numerous challenges. Ensuring the historical accuracy and integrity of stories is paramount, but it is equally important to ethically represent the data, being mindful of its significance and potential sensitivities. Physical and temporal constraints at these sites can limit the narratives but also present unique opportunities to curate and present information in innovative ways. With the rise of novel technologies, such as Virtual Reality (VR) and Augmented Reality (AR), there is an increasing potential to engage the senses more deeply, creating immersive experiences that bridge the past and present. Yet, balancing educational objectives with audiences' diverse needs and expectations remains a complex task. Lastly, the intersection of preservation, eliciting emotions, and navigating controversies is a delicate task requiring sensitivity and skill. Innovative strategies for conveying information enhance and complement traditional methods, ensuring that heritage is preserved and appreciated in modern contexts. However, with these new strategies come new challenges and opportunities. Issues that persist in traditional methods now take on new dimensions and implications, making it especially important to address them when adopting novel approaches. In the following Section 2.1, we dive deeper into some of the central challenges and opportunities we aim to address later in our adapted design space.

Challenges and opportunities

Historical Accuracy & Integrity Incorporating data-driven elements into narratives about cultural heritage sites poses a challenge in preserving historical accuracy and integrity (Bradley, 2005; Muller,2002; Manzuch, 2017). It is essential to stay true to original sources, ensuring that both tangible and intangible historical assets, once digitized, genuinely mirror history instead of unintentionally distorting it (Boyd Davis et al., 2021; Müller, 2002; Koller et al., 2009; Brown and Waterhouse-Watson, 2014). There is also a risk of oversimplification when translating these assets into data or visualizations (Santana Quintero et al., 2020; Koller et al., 2009). Many historical records offer data that are either ambiguous or incomplete, because they often only reveal a small fragment of a bigger context (Vancisin et al., 2023), possibly due to deliberate destruction, or if they have only had a specific focus. (Brown and Waterhouse-Watson, 2014). Interpreting this data demands precision (Windhager et al., 2019; Liem et al., 2023; Koller et al., 2009) and a heightened awareness of how contemporary biases might influence our perceptions of the past (Prutsch, 2013).

Ethical Representation Beyond accuracy and integrity, cultural heritage sites must also consider the ethical dimensions associated with digitizing and representing tangible and intangible historical assets (Manzuch, 2017; Rich and Dack, 2022). When curating displays or constructing narratives, it is typically necessary to approach the subject with respect. This is particularly true when recounting events that may have traumatic histories (Fisher and Schoemann, 2018). Digital recreations of tangible and intangible historical assets, demand a careful balance between shedding light on historical facts and avoiding unintentional bias or misrepresentation, which, e.g., could arise from an

unintentionally biased perspective of the creator of the digital recreations (Thompson, 2017) or simply due to uncertainty related to the underlying historical assets, to try and minimize these biases, creators need to reflect upon their own biases and reflect these in a transparent manner to the reader. Ultimately, an ethical obligation towards the recipients is associated with the representation of digitized tangible and intangible historical assets, and it is an aspect that is crucial in digital storytelling at heritage sites, where there is a need to respect the complexities and sensitivities of heritage narratives (Hargoodet al., 2022; Trichopoulos et al., 2023).

Physical & Temporal Constraints Spatial and temporal considerations inevitably influence storytelling in the physical domain of heritage sites (Rossiet al., 2017). The spatial arrangement of a heritage site can guide or even dictate the narrative flow (Benouaret and Lenne, 2015; Lombardo and Damiano, 2012). Moreover, the narrative must be crafted considering visitors' limited time at a site. The challenge is to ensure that, within this brief window, visitors gain a coherent and enriching understanding of the narrative being presented.

Embracing Technology & Engaging the Senses Heritage sites have the unique potential to craft multisensory experiences, unlike many traditional storytelling mediums. For example, Katifori et al. (Katifori et al., 2018) highlight multi-sensory interactions' transformative role in enhancing visitor immersion, emphasizing the shift towards emotive virtual experiences through personalized storytelling. In their research on the CHESS prototype, Katifori et al. (Katifori et al., 2014) showcased how personalized, interactive digital storytelling experiences can significantly elevate visitors' experience. While the potential of emotive virtual experiences in heritage sites is vast, there are also inherent challenges. For example, an overemphasis on technology can overshadow genuine historical value, potentially reducing the experience to mere entertainment (Rich and Dack, 2022). Some visitors might also feel that digital augmentation hinders a direct connection with heritage (Manzuch, 2017). As narratives become more emotive, there is also a risk of modern biases affecting the representation (Prutsch, 2013).

Educational Ambitions & Audience Diversity Heritage sites can be said to operate at the intersection of engagement and education. While the narratives must be compelling, an underlying educational mission seeks to inform and enlighten visitors about historical, cultural, or scientific facets. Complicating this mission is the vast diversity of the audience. With visitors spanning different age groups, cultural backgrounds, and levels of prior knowledge, the storytelling needs to be inclusive and universally accessible. As discussed by Mason (Mason, 2004), communication models at heritage sites have traditionally emphasized a unilateral approach. In this model, the heritage professional is the transmitter, sending a singular, one-way message to the visitor. However, such a method is limiting. For narratives to resonate with visitors, they should be formulated with a holistic understanding of the visitor's context. This encompasses their background, including prior experiences, learning styles, interests, and motivations; the sociocultural backdrop of their visit; and their interaction with the heritage site's spatial and tangible aspects (Lombardo and Damiano, 2012; Rizvic et al., 2019).

Related work

As laid out in Section 2, our work touches on several aspects. Yet, in terms of related work, we primarily summarize prior work that analyses data-driven and narrative storytelling, identifying central and vital building blocks for constructing narrative stories. Segel and Heer established the foundational work on data-driven and narrative storytelling in their paper (Segel and Heer, 2010). They introduced key practices primarily centered on the journalistic reinterpretation of data into compelling visual narratives. Segel and Heer categorized these narratives based on three primary criteria: genre (the main visualization technique utilized), visual storytelling tactics (involving visual structuring, highlighting, and guidance through transitions), and narrative structure strategies (encompassing ordering, interactivity, and messaging). Subsequent research has expanded upon Segel and Heer's foundation. For instance, Tong et al. (Tong et al., 2018) conducted a comprehensive review of storytelling in data visualization, analysing various visual storytelling elements in scientific publications. Their examination addressed questions such as" Who?" (related to authoring tools and user engagement)," How?" (involving narratives and transitions), and, "Why?" (concerning memorability and interpretation). They also extended Segel and Heer's classification by introducing a second layer of categorization, which examines the sequence of events (linear, user-directed path, parallel, and random). In the realm of newer web-based and data-driven stories, Stolper et al. (Stolper et al., 2016) and Gershon (Gershon and Page, 2001) expanded upon Segel and Heer's foundation. They introduced additional genres (e.g., timelines), narrative structure tactics (e.g., interactive brushing and linking), messaging (e.g., audio), and visual storytelling tactics (e.g., linking separated story elements). Some researchers have acknowledged Segel and Heer's work while developing their own frameworks. For instance, McKenna et al. (McKenna et al., 2017) identified seven factors contributing to the flow of visual narratives. Latif et al. (Latif et al., 2021) examined the spatial arrangement and interactive linking of visualization and text, emphasizing its impact on reception, engagement, comprehension, and recall. They explored various methods to integrate visualizations into the narration seamlessly. Zhao and Elmquist (Zhao and Elmqvist, 2023) introduced their unique design space and analysis framework. Their framework includes dimensions such as audience cardinality (describing the number of storytellers and recipients), space and time (impacting the delivery and storage mechanism for data driven storytelling), media components (defining the composition of data-driven storytelling), data components (conveying data from the storyteller to the viewer), and viewing sequence (describing the level of interactivity associated with a storytelling artifact). The framework aims to provide practical guidance for creating Stories. In a related context of narrative storytelling, Kim et al. (Kim et al., 2018) introduced the concept of story curves. They applied this visualization technique to analyse narrated fiction's (non-)linearity, particularly in movies, drawing inspiration from Genette's nonlinear narrative patterns (Genette, 1983). Kim et al. extended classical patterns with new ones, exploring how historical events are ordered in narration.

Additionally, Roth (Roth, 2021) contributed to cartographic design by offering three perspectives on visual storytelling. These include foundational plot patterns, which follow the three-act structure and incorporate basic plot patterns. While not directly connected to Segel and Heer's work, these perspectives enrich the overall landscape of research in narrative storytelling.

From the perspective of emergent and computational digital storytelling, Trichopoulos et al. (Trichopoulos et al., 2023) also touch upon the fundamental elements of storytelling that we have previously mentioned. Notably, their research focuses on contemporary works encompassing authoring tools, systems, applications, methods, frameworks, and case studies. They categorize these works based on aspects like scope (e.g., education, cultural heritage, games), media (including tangible interactive digital narrative, gesture recognition, embodied digital storytelling, VR/AR, video, and animation), and interaction methods (e.g., cards, paper objects, embodied replicas, special objects, hand gestures). This perspective provides insights into how technology is reshaping storytelling, with computers and algorithms increasingly integrated into the narrative creation and presentation processes.

Most recently, a state-of-the-art survey by Kusnick et al. (Kusnick et al., 2023) focuses on visualization-based storytelling in digital humanities and cultural heritage. Their paper builds directly upon the concepts and various aspects introduced in the earlier mentioned work and surveys prototypical storytelling examples relying on visualizations. Based on the prior work and the analysis of prototypical visualization-based storytelling examples, a comprehensive and robust design space is assembled that defines the vital building blocks for creating visualization-based narratives in the digital humanities and cultural heritage domain.

Survey scope

In this section, we will dive into 4 examples that showcases the overall structure of the examples analysed throughout our survey and how they use elements of the VBS design space to create their respective sites. Examples 1 and 2 are based on sites that use a wide variety of elements of the VBS design space. In these examples, we will also dive into how their usage can showcase how we can extend the current VBS Design space to better encompass the needs of VBS for cultural heritage sites. Examples 3 and 4 are of sites with a low variety of methods that correlate with the VBS design space where we will dive into how they handle the communication with the visitor. Based on these examples we will then look into the difference in impact the sites have. The four examples are taken from the analysis seen in Tables 7 and 8 are showcased because of their polarization in regard to how they showcase information to the end user and therefore give a wide viewpoint on how elements of the VBS design space are used on cultural heritage sites with a focus on HNP.

Example 1: Online database by the international Institute for Holocaust research, Yad Vashem (Yad Vashem, 2023). This online database provides information about the movement of Jews from Austria, Belgium, Czechoslovakia, Denmark, France, Germany, Greece, Italy, Luxembourg, and the Netherlands between 1939 and 1945. The site uses a combination of Topography, infographics, animations, timelines images, and text to convey a massive dataset and give the user the possibility to have a macro-overview of all information but also allow the user to find specific locations and people. They give the viewer a short linear exploration section where they define the project and what it can be used for. Afterward, they encourage free exploration of the data available. The data is represented organically depending on where you are on the map. Each entry has a little overview

section that you then can dive deeper into, which encourages the free exploration nature of the site. They also offer a more direct form of search in their data set at all times.



Example 1: An online database provides information about the movement of Jews from Austria, Belgium, Czechoslovakia, Denmark, France, Germany, Greece, Italy, Luxembourg, and the Netherlands between 1939 and 1945.

Example 2: Online application by Memorial and educational site, house of the Wannsee conference (Aleksandra Bänkowskaa, Flavia Citrigno (GHWK), Christoph Kreutzmüller (GHWK), 2023). This online application reviews the statistics created by Adolf Eichmann for the "final solution." The site uses a combination of Text, imagery, sound, video, Scrollytelling, infographics, interactive maps, and timelines. The site begins with leading the user through a Linear exploration, setting up the background information about Eichmann's statistics for the final solution, and then leads the user to an interactive map where they have a free exploration of the 11 million victims, different statistics, and also the opportunity to dive into the individual's story. The site uses different VBS tools, to create a certain mood and immerse the viewer in the data available. This creates a connection to the data and creates a personal experience instead of just looking at the data objectively.



Example 2: Website that uses a combination of Topography, infographics, animations, timelines images, and text to convey a massive dataset and give the user the possibility to have a macro-overview of all information but also allow the user to find specific locations and people.

Example 3: Web app that displays a digital tour of the female concentration camp of Ravensbrück (Europa-Universität Viadrina, 2023). The web app gives a linear exploration, where you are first introduced to a 3-minute video with narrative audio that takes you on a journey of the site of the concentration camp as it is today, you can read about the area and the information that is accessible. The site uses a minimum of VBS tools to display its information and confines itself to a very narrow subject.





Example 3: A digital tour of the female concentration camp of Ravensbrück.

Example 4: Virtual tour of the commander's house of Westerbork by the Institute of Campsscapes Westerbork (Campscapes Westerbork, 2022) The Virtual tour starts with a linear exploration, where the viewer is given background information of the area, through video and text, afterward users are led to a cloud point based rendition of the commander's house, which is freely explorable for the user. Text popups are shown throughout the house when the user gets close to points of interest. The site uses a variety of VBS tools, video, audio, text, imagery, virtual tours, and multiple exploration forms and combines their usage to showcase one specific area of interest focusing on creating a presentation that aligns a single entity orientation, the commander's house. They do not use any form of search-ability or User interface that guides the viewer, which creates a more slow-paced immersive experience, but the trade-off is a less effective informative journey.



Example 4: A virtual tour of Commander's house of Camp Westerbork

When comparing the four examples listed above, we can see that certain elements, such as text, video, film, or interactive media can be used regardless of the scale of the information being given, their combination is often more aligned in how they can immerse the end user in the data represented. We can also see that visualization types such as interactive maps, timelines, and infographics often are used when conveying larger data sets. Regarding exploration all the sites have some form of Linear exploration in the beginning to immerse the user, but then afterwards shift to free exploration, Examples 1 and 2 give the option to bypass this linear exploration if needed. We started with an initial pool of 174 VBS examples, which were similar in nature to the four presented examples. This collection underwent a filtration process, described in the subsequent section, wherein certain examples were omitted according to certain exclusion criteria.

Search procedure

The VBS examples discussed in this survey were crowd-sourced from the consortium members affiliated with the MEMORISE project. These members comprise professionals operating in the heritage sector. The exclusion criteria used to filter out VBS examples are described as follows:

Restricted Access We eliminated VBS examples if they were not easily accessible e.g. due to broken links or content hidden behind paywalls.

Location-Dependent Usability Examples were also excluded if their use was limited to specific geographical locations.

Concept Demonstrations Moreover, we excluded examples that were in the initial stages of development or served merely as demonstrative proofs of concept without a functional, user-ready implementation or product.

Through the application of these exclusion criteria, we ended up with a final pool of 129 VBS examples. The pool of 129 VBS examples were brought down even further through a preliminary analysis according to the design space put forth by Kusnick et al. (Kusnick et al., 2023), with the purpose of obtaining a varied sample of VBS examples. Consequently, we ended up with 20 VBS examples. The preliminary analysis was defined by looking into which sites used elements of the VBS design space in a broader sense by looking if the used forms of media types, vis types, story threads etc. And then filtering out the sites that did not fall into these categories or made little use of visualizations

Survey Methodology

In the following, we outline our analytical methodology, designed to uncover current design trends, and explore potential avenues within visualization-based storytelling (VBS) for cultural heritage sites.

1. The further analysis, detailed in the analysis section, prompted the refinement of the existing design dimensions, leading to the evolution of a modified and extended design space, accommodating the nuances and new aspects discovered during the analysis.

2. After our initial analysis, we augmented the design space further. The augmentation was informed by the challenges and opportunities identified the background section, contributing to an extension to the current design space. This further extended design space serves as the foundation for subsequent analysis of the 20 VBS examples. This approach enabled us to discern specific trends and evaluate how well current VBS practices address challenges and seize opportunities. Our research is based on finding which elements of the VBS design space are most used and how these common trends are presented in the circumstance of cultural heritage sites with a focus on HNP, but we do not investigate how these elements are being engaged with by the end user. The user experience is important in how and when to implement different VBS methods, but this implementation is outside of the scope of this paper.



Figure 5: Survey findings of primary and secondary VBS tools

Analysis

To define how the VBS design space is relevant and used in the cultural heritage spaces we created a survey of technology-based projects relevant to cultural heritage sites with a focus on HNP, these were then defined based on the current VBS design space to ascertain which tools were relevant and which tools could be added. The survey contained 129 different sites that were categorized in the VBS design space to define which primary and secondary means of communicating they used as seen in Figure 5. Based on our findings we could see that text and images are used as the primary way to convey information in 35 percent of all sites and are used in all sites as a secondary means of communication. The other media types, film, and visualization were each used roughly 20 percent of the time as the primary way of communication while virtual tours were used 12 percent of the time. audio, virtual reality, 3D renders, and interactive media such as video games were used 9 percent of the time as the primary way of communicating.

The overall navigation of these sites were conducted through free exploration 70 percent of the time, while a more linear approach was prevalent in 20 percent of the cases. The last 10 percent were based on a combination of linear and free exploration. To showcase data sets most sites used interactive maps and timelines to give the target user the possibility to quickly filter through the data. The effectiveness of the implementation of these visualization tools is further discussed in our accessibility section based on these findings we then chose 20 examples that correlated with our findings and dove deeper into their specific structure and how they aligned with the current VBS design space.



Figure 6: Narrative exploration.

To identify how the VBS design space is relevant in the context of cultural heritage sites with a focus on HNP, we aligned our findings together with the pre-existing VBS design space created by (Kusnick et al., 2023) to highlight which areas cultural heritage sites specifically could benefit from it in future projects. We segment these findings into two tables, VBS means and VBS presentation. The means covers, media and vis types, story threads, composition, interactivity, and target devices, whereas VBS presentation covers, entity orientation, story complexity, linear/non-linear, and plot patterns as explained in the background section.

	170: Zeitzeugenportal	162: VR commanders house	149: Topographie der Gewalt	135: Stolpersteine NRW	134: Stolen memory	133: Questioning Eichmann	131: Spuren auf Papier	112: Memory loops	105: Mahn und Gedenkstätte	101: Lediz	Туре	vaa, veebnig meniones		078: His name is my name	068: Frauen als Opfer der T4	060: Eva stories	056: Entdeckungstour	044: The liberation AR	040: Danish jews in Theresienstadt	013: Der Anfang vom ende	011: OTD 1945	003: Zwangsterilisation in Lüneburg	Type	ID and Name	
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Figure 7: VBS means

Visualization based storytelling means

To define which elements of the VBS design space are preferable regarding cultural heritage sites with a focus on HNP we first need to categorize what means are necessary to convey information correctly to the end user. To get a clear definition of how different VBS means are used we took the 20 examples from the survey that used a variety of methods to create their sites and placed them into table 7 to create a visual overview. As seen in the table there are different methods more commonly used through our samples of cultural heritage sites with a focus on HNP and some that are used rarely or never throughout the examples.

Media types Throughout the 20 examples used in Table 7, we can see that there is a broad variation of Media types used to engage with the user, The most used is text and imagery, either as a primary or secondary source. Audio is also a big indicator in media types but is more often used as a secondary element, either as background music as in the Instagram story about Eva Heyman (Kochavi and Kochavi, 2019), or background sound to set an atmosphere, as the sound of a typewriter in the web page about Eichmann (Aleksandra Bánkowskaa, Flavia Citrigno (GHWK), Christoph Kreutzmüller (GHWK), 2023), an accessibility option as in the web page about the liberation of Dachau (Deinert and Maier, 2020), or as a means of getting more information about certain topics or as a storytelling voice, telling the story audio Vise and not using text as in the Instagram story about Gerrit Jongsma (Jongsma and Oneill, 2021), which leaves it as a media type that contributes in a variety of ways. Visualizations are used in most examples, but their usage varies. Most sites use visualizations as a secondary means to back-up their texts but often do not utilize them as a primary way of exposition.

Vis Types The usage of different visualizations has a clear differentiation between one another, timelines, maps, and interaction are used on over half of the examples, often in combination with one another as used in the web page showing memorial stones in Germany (WDR, 2023), either as interactive maps that change depending on location or time period, or timelines that showcase different events through either different perspectives or areas. Data sets are fairly used as well, often to compartmentalize either people or objects regarding events. The most uncommon visualizations are graphs and charts. A hypothesis for the reasoning of this is that when highlighting elements of cultural heritage, it often surrounds delicate subjects that require empathy. In contrast, charts and graphs often can feel too removed from the subject and transform tragic events into mere numbers, this effect has been seen regarding visuals, where when focusing on traumatic events on an individual level we create more empathy for a given situation than when we investigate large scale data (Azevedo et al., 2021) But this is not necessarily correct when we look at example 133 (Aleksandra Bánkowskaa, Flavia Citrigno (GHWK), Christoph Kreutzmüller (GHWK), 2023) we see usage of both graphs and charts, without removing us from the people they are about. This is achieved through the usage of transitions and animations from individual portraits of victims affected into small points in a graph or chart. This results in a direct correlation between the people affected and the data shown, the site also uses a combination of linear narrative to immerse the viewer before letting them freely explore the site.

Story threads Most examples use text in either a primary or secondary form to create the story threads seen on their sites, often combined with temporal succession to showcase different elements and to give the viewer a better understanding of the elements they read about. When looking at common practices in ascertaining viewer retention regarding story threads our research aligns well with research from Vaniscin that displays the direct correlation between combining different methods of letting the viewer taken information and viewer retention (Vancisin et al., 2023) Throughout the examples we also can see that there is not any given type of story thread that is not being used, although juxtaposition is the less used element.

VBS composition Based on the examples most compositions are based around 2 distinct types of VBS compositions a common occurrence is a combination of mixed narrative and exploration and stories with multiple visualizations. This combination allows the user to break away from the author-driven pathway and creates the opportunity for the viewer to interact with the different elements and allow them to dive into details in areas they deem relevant as in the web page of Topography of violence (The Jewish Museum Berlin, 2023). We see a few cases of timeline visualizations become apparent, which goes against our overall survey, which indicated a high usage of timeline elements, this is likely because of the small sample size of the examples which gives an unbalanced picture of the overall survey.

Interactive implementation There is a big variant between which forms of interactive implementations are being used in the examples. Scrollytelling, animations, and slideshow elements are most prevalent, creating engaging elements on the more text-heavy examples. This correlates with prior research that showcases that these interactive elements help with keeping viewer retention and allow the viewer to take in more information since it comes from various sources (Vancisin et al., 2023). One element that was not seen used throughout the 20 examples and that also had a low correlation throughout the survey of the 123 examples is data comics. The reasoning behind this could stem from the fact, that there are few examples in how to best use data comics in general and therefor are harder to implement (Bach, 2019).

Target devices for target devices, we can see that all examples are created to be used on either a desktop, mobile device, or tablet. The outliers in this regard are VR AR and static displays. While wall displays are not used in any of the examples. This correlates with the boundaries of the survey where we excluded onsite examples. The only example that has a physical attribute was the web page Traces of Paper (Wehnen Memorial, 2021) which was an interactive game, that also allowed a printable version that you could play together with other people.

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	ID and Name	Туре	011: OTD 1045	013: Der Anfang vom ende	040: Danish jews in Theresienstadt	044: The liberation AR	056: Entdeckungstour	060: Eva stories	068: Frauen als Opfer der T4	078: His name is my name	099: Keeping memories	Type	101: Lediz	105: Mahn und Gedenkstätte	112: Memory loops	131: Spuren auf Papier	133: Questioning Eichmann	134: Stolen memory	135: Stolpersteine NRW	149: Topographie der Gewalt	162: VR commanders house	170: Zeitzeugenportal	
	Objects			1		Π			Π	Γ						T	Γ					T	Γ
Entit	Persons		t										F			F	t	╞			F		t
y-orie	Sets		T											t		t	1	T	t		+	Γ	t
ntatio	Events		t							H			F		Г	t		t				t	r
5	Places		T	T						Γ			F			Γ		F				T	Ē
	Synchronic: Simple																						
Ň	Synchronic: medium																						
tory o	Synchronic: hard																						Γ
omple	Diachronic: Simple						Π		Π					Γ			Γ	Γ					Γ
exity	Diachronic: Medium									Π			Γ			Γ							Γ
	Diachronic: Hard																						
	Diachronic: Complex																						
	Actor Biography																						
	Object Biography			Τ				Π		Γ			Γ		Γ	Γ	Γ					Γ	Γ
	Place Biography		Γ															Γ					Γ
Stor	Hybrid Biography		T													T	Γ		Γ				
y Sch	Biography Sequences																						
emata	Biography Bundles																						
	Inverted Trees																						
	Trees																						
	Larger Topic/era		T	T						Γ						Γ		T	Γ		Γ		Γ
	Larger topic / multi-era																						
	Genesis Plot																						
	Emergence Plot									L					L		L						L
Plo	Destruction Plot		_	_											L								L
ot Patt	Metamorphosis Plot			_						L													L
erens	Cause & Effect									L													L
	Convergence																						L
	Divergence																						
	Oscillation																						
	Set-up																L						L
Stor	Rising conflict / Supporting facts			_											L								L
y Arc 8	Climax/ Main insight																		L				L
& Hoo	Resolution / Conclusion			4											L								L
*	Story hook			_																			L
Linea	Linear Storytelling																						-
7	Non- Linear Storytelling					\vdash																	H
Fa	Factuality		+	+											-		-		-				⊢
rctuali	Fictious elements		+	-									-	-	\vdash				-	-			⊢
ţ	Fictious story world		+	+	+	Η			H				\vdash	╞	\vdash		\vdash	\vdash	\vdash	\vdash		+	⊢
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her																							

Figure 8: VBS presentation

Visualization based storytelling presentation

Most cultural heritage sites we investigated in our survey focused on portraying people, events, and specific places, through a non-linear storytelling model, with free exploration for the user, as can be seen in figure 6: This model gives the viewer the opportunity to freely explore the data available, but it risks losing the viewer's interest since key points might be overlooked or not be properly highlighted for the viewer. On the other side of the spectrum, 20 percent of the sites used linear storytelling, which guided the viewer through a predefined route. This method enhances the chance for viewer immersion since you decide in which rate and fashion the user digests information. The drawback of this solution is that the viewer might lose interest if the information does not seem relevant to them, even if it might be. Regarding which storytelling medium the different sites used, we saw a small segment of 10 percent that used multi-linear storytelling and mixed storytelling. Multi-linear was defined through different segments that each had their own linear progression but would intertwine with other segments. This was seen mostly in combination with highlighting individual persons' stories throughout a historic event and how their own linear stories affected other stories and elements around them. Mixed storytelling was used mostly in a combination of visualization types such as maps or interactive media, such as 3D renders or point cloud renders in combination with voiced segments. The voiced segments would guide you through a linear narrative and then let you freely explore. This would then shift throughout the narrative. These Narrative paths gave the viewer a more structured experience, while still maintaining their agency, which could result in a bigger viewer retention, since the site creates a predefined path that the viewer can follow, but also allows them to differ from this path if the information given is not relevant. This is an aspect that needs more research to clearly define the benefits and drawbacks, but it is certainly an aspect that deserves further attention.

Entity orientation Most examples have an entity orientation that focuses on people, often seen in combination with either specific locations or events. The area that has the least focus is object entity orientation, this is true in the 20 examples we showcase in figure 8: but also, in the overall survey.

Story complexity Story complexity differs from example to example and has a great variation. One pattern that can be observed is that there is a greater degree of examples that rely on more complex synchronic story complexity accompanied by a simple diachronic complexity as seen in the topography of violence site (The Jewish Museum Berlin, 2023) this allows the examples to showcase a great number of entities, while keeping the different elements simple and tangible for the viewer, whereas the opposite would be if an example wanted to showcase a small number of entities and go into depth with those.

Story schemata Just as with the object orientation, we see a greater number of examples that rely on actor biographies. Often in combination with biography sequences or biography bundles. One element that is not used throughout the examples is the usage of inverted trees and a small number of examples use trees as Story schemata as in the webpage about the Wansee conference, where the viewer can go into any room of the house from the front page (Chenchanna and Gogelein, 2022),

which shows that this is not a common way to explore VBS on cultural heritage sites with a focus on HNP.

Plot patterns There is an overall lack of plot patterns in the examples of 8: The lack hereof can be reflected by the substance of the examples. Many of them refer to firsthand experiences and are portrayed as objectively as possible, which discourages plot patterns in Favor of actuality as in the Keeping Memories web page (Dive Project, 2023). Story arc/hook many examples use one form of story hook to engage with the viewer at to get their attention, although the two tropes used mostly are rising conflict/supporting facts and main insight/climax. This aligns well with the fact that most examples are focused on people and their diaries and testimonies which all have a form of narrative journey inside them.

Linear/Non-Linear There is not a clear favourable method between linear (Euthanasie - Gedenkstätte Lüneburgg e.V., 2022) and non-linear (Michael Melian , 2010) storytelling in the given examples, but we can see that many examples use a combination of linear and non-linear storytelling by first using a linear method to convey the main insights of the site and thereafter letting the viewer freely explore as they see fit (The Jewish Museum Berlin, 2023)

Factuality There is a large representation of examples that use factuality and uncertainty on their sites, this is because of the nature of the information given from cultural heritage sites since they often are focused on historical events and firsthand accounts. Many sites also include the uncertainty of some of their information, either because they lack crucial information about certain elements or because the information given is eyewitness accounts. One example combined the usage of factuality and fictitious elements, by creating a playable diary that took basis in real-life events and diary entries, but also took creative liberty to enhance the experience for the viewer (Wehnen Memorial, 2021)

Extended design space

During our survey, we have identified several commonalities in the cases we have reviewed. A recurring theme revolves around the use of source material, which includes testimonies, diaries, and official documents. In our new conceptual framework, we have emphasized the significant role of the nature of the source material, considering it to be of greater importance than just the format of the visual-based narratives (VBS). As seen in Figure 7 and 8, we have changed the original design space from Kusnick et al (Kusnick et al., 2023), partly to delve deeper into fewer of the elements when it comes to media types and VIS types, which we have found relevant for cultural heritage sites with a focus on HNP, so we have looked into VBS means and selected those that are adequate for the sites we have looked at in our survey. We ended up with media types: Images, text, and audio. In the new design space, the images are divided according to their function, either first hand, which is understood as images that directly support the text, or second hand, which are images that are present to help set an atmosphere. We have looked at the origin of text and audio, which is covered

by testimonies, diaries, and official documents. Thus, media types are related to media source types related to media type in Figure 11 (light green for types and darker green for sources). We have the same division for vis types, where we have selected from the original design space just three types: interaction, timeline, or map, since these three cover very well the types we see in the examples we have been going through for this survey. These are associated with VIS source type related to VIS type with a darker shade of green: testimonies, diaries, and official documents. In addition, we have added a couple of categories to our new design space (the beige boxes) where we look at the actual way the story is told in the examples of cultural heritage sites with a focus on HNP that we have looked at: whether it is linear, nonlinear or whether it is a mix. In addition, we look at the complexity of the accessibility tool options, where simple is 1 tool: usually the ability to switch to another language. Medium is 2-3 options, for example, the option for easier-to-understandable text or the possibility of reading aloud. Complex is the possibility of 4 or more accessibility tools. Testimonials, as a fundamental type of source, encompass different modalities, including textual, visual, and auditory elements. In cases where the source material takes the form of images, it is common to find accompanying textual transcriptions, improving accessibility. Similarly to testimonies, diaries exhibit a comparable duality in terms of representation formats within the indigenous design paradigm, manifesting as both textual and visual representations. It is noteworthy that our analysis did not reveal examples of diaries that were conveyed through oral or visual means (audio or video), although this possibility is not excluded. Official documents, a frequently observed source category in VBS narratives, come in various forms that include textual and visual representations. Notably, it is common for official documents to lack a text transcript, suggesting a potential gap in accessibility for certain VBS consumers. Images can be categorized into distinct subcategories, namely, first-hand, and second-hand. This classification stems from the prevalent usage of images, primarily serving one of two overarching purposes: either as supportive visual aids to complement textual content or as mood-defining elements within the context of a visual narrative. In the following sections, we will attempt to describe how these source types are used within the different media types according to the initial design space, and how images are divided into first hand and second hand.



Figure 10: Accessibility

Accessibility

When looking into how to use the VBS design space to create a tailored experience in the field of cultural heritage that also aligns with the goal of creating inclusivity for a diverse audience spanning different age groups, cultural backgrounds, and levels of prior knowledge as mentioned in the background section we also have to account for the accessibility of the given sites, as of 2011 15 percent of the world population have a form of disability that limits their access to the internet (WHO, 2011), to create a design solution that also accommodates this segment of the public. Through our survey we defined which forms of accessibility are currently available on cultural heritage sites with a focus on HNP, to define the current standard. The data found was divided into 3 different categories. The function to switch languages, the minimum of one function to help with reading comprehension, colour-blindness, deafness, blindness, etc. Sites with more than one functionality of the ones mentioned in the previous sentence. Our findings show us that 47 percent of sites have any given form of accessibility. Out of these 47 percent that had accessibility options 74 percent of them were to change the language from one to another. 17 percent had one form of accessibility, sound, easy reading, colour-blindness, sign language, etc. In this specific survey we define colour-blindness accessibility as when the user can interact with the site to change the specific colours, we do not account for sites that have colour schemes that by default are colour-blind friendly. 9 Percent had a minimum of three options and 5 percent of the sites had these options on their front page. These statistics show that there is a lack of accessibility options on cultural heritage sites, which results in a segment of the population being unable to interact with them. The cultural heritage sites that did have a minimum of 3 accessibility options do however highlight an effective method of including this part of the population and should be used as an example to further study the most effective way of incorporating accessibility options.



Figure 11: Images

Images

For this survey, we, as mentioned, subdivide the category images from the VBS means, as derived from the prior survey into two distinct subcategories: namely, first-hand, and second-hand. It is essential to underscore that, in the context of this survey, the following definitions provide a detailed explanation of these categories, as presented in Table 1.

Table 1: Interpretations of Visual Content Subcategories

Category	Description
First Hand	This classification encompasses images featuring individuals, scenarios, premises, or objects that act as supplementary elements to textual content. Examples include the portrayal of individuals or families presented within the text, in descriptions or interviews. This category also comprises images that illustrate scenarios or localities alluded to in the textual narrative, as exemplified when a text pertains to transportation, and includes an illustrative depiction of a freight car replete with disquieted passengers.
Second Hand	Second-hand visuals encapsulate imagery designed to evoke specific moods or atmospheres, often achieved through the inclusion of intentionally blurred background images that enhance the desired ambiance conveyed within the text.

The rationale behind the subdivision of images into these three distinct categories lies in the extensive analysis of all the examples analysed within the framework of this survey, which inevitably illustrations into one of the aforementioned two categories. allows categorizing Several illustrative instances that effectively employ the two subcategories within their online resources can be cited. One noteworthy case is the website dedicated to the topic of forced sterilization in Lüneburg (Rudnick, 2022), which adeptly leverages both first-hand and second-hand images through the integration of portraits and images of documents. Specifically, this resource adeptly employs portraits as second-hand images, when incorporating them as background imagery preceding textual content. Subsequently, these same portraits reappear within the scrolling narrative, strategically interwoven with the textual content, thereby facilitating a more comprehensive understanding of the narrative as a first-hand image. Similarly, the webpage dedicated to commemorating women who perished in the context of Action T4 (Euthanasie -Gedenkstätte Lüneburg e.V., 2022) demonstrates a parallel approach. Furthermore, the Stolen Memories webpage artfully combines written content with succinct video clips to convey narratives, while concurrently employing portraits to reinforce the textual information. Additionally, the resource integrates visual representations of objects that are relevant to the textual content, thus enhancing the comprehensibility and impact of the conveyed information (Arolsen Archives, 2022).

	170: Zeitzeugenportal
	162: VR commanders house
	149: Topographie der Gewalt
	135: Stolpersteine NRW
	134: Stolen memory
	133: Questioning Eichmann
	131: Spuren auf Papier
	112: Memory loops
	105: Mahn und Gedenkstätte
	101: Lediz
	Туре
	099: Keeping memories
	078: His name is my name
	068: Frauen als Opfer der T4
	060: Eva stories
	056: Entdeckungstour
	044: The liberation AR
	040: Danish jews in Theresienstadt
	013: Der Anfang vom ende
	011: OTD 1945
	003: Zwangsterilisation in Lüneburg
	Туре
Text Audio	ID and Name
Media types Other	

Figure 12: Text and audio

Text

When subdividing text into diaries, testimonies, and official documents in this survey, it is because the majority of data comes from these three sources, and partly because we find that consideration must be given to how data in these sub-categories can be visualized. It must be constantly remembered that one must consider both ethical and legal aspects of communicating and disseminating personal memories and stories while at the same time conveying that both diaries and testimonies are subjective without insinuating that the narrator is lying. it is also important to note that even official documents from that time can be of a questionable origin. The web page on this day 1945 (Buchenwald and Mittelbau-Dora Memorials Foundation, 2021) is an example of a web page using testimonies, diaries, and official documents to tell the story of the last few months of the Buchenwald and Mittelbau Dora Concentration Camps. With blog entries on a timeline starting in January 1945 to the end of May, many little stories of the concentration camps are told in short entries supported by images of places, people, and documents. Both diaries and testimonies are qualitative, subjective memories, and even if quantitative data is present within them, you may need to be careful when visualizing, as quantitative data on a graph or in a chart will often be perceived as truths and not as subjective memories by the recipient. Studies have shown that some researchers use graphs to make their texts appear more scientific than they are and that this is an effective tactic (Isberner et al., 2013), the same applies to the opposite, although there is not much research of the field yet.

	Entity Pe	orient ersons	ation		Enti orienta plac	ity ation :es
ID and Name	Victims	Survivors	Prosecutors	ID and Name	Current	Past
Туре				Туре		
003: Zwangsterilisation in Lüneburg				003: Zwangsterilisation in Lüneburg		
011: OTD 1945				011: OTD 1945		
013: Der Anfang vom ende				013: Der Anfang vom ende		
040: Danish jews in Theresienstadt				040: Danish jews in Theresienstadt		
044: The liberation AR				044: The liberation AR		
056: Entdeckungstour				056: Entdeckungstour		
060: Eva stories				060: Eva stories		
068: Frauen als Opfer der T4				068: Frauen als Opfer der T4		
078: His name is my name				078: His name is my name		
099: Keeping memories				099: Keeping memories		
Туре				Туре		
101: Lediz			_	101: Lediz		
105: Mahn und Gedenkstätte				105: Mahn und Gedenkstätte		
112: Memory loops				112: Memory loops		
131: Spuren auf Papier				131: Spuren auf Papier		
133: Questioning Eichmann				133: Questioning Eichmann		
134: Stolen memory				134: Stolen memory		
135: Stolpersteine NRW				135: Stolpersteine NRW		
149: Topographie der Gewalt				149: Topographie der Gewalt		
162: VR commanders house				162: VR commanders house		
170: Zeitzeugenportal				170: Zeitzeugenportal		

Figure 13: Persons

Figure 14: Places

Person and places

We have further disaggregated the VBS presentations people and places into additional subcategories. A detailed exposition of all these new subcategories will be provided in the subsequent sections. In the context of this article, the classification of individuals into distinct subcategories, namely victims used to describe people who died in the holocaust, survivors being people who survived the holocaust, and persecutors, is carried out as an apparent categorization. This categorization is employed because these specific groups constitute the focal subjects throughout the example's instances examined in the article. Occasionally, the narrative perspective may be assumed by an individual who can be characterized as a descendant of one of these three categories or as a historian. Nonetheless, regardless of the perspective assumed, the narrative consistently centers around one of the categories. The tour of the commander's house in camp Westerbork (Campscapes Westerbork, 2022) is an example of how the story can be told from the persecutors' side, and somehow still tell the story of the victims and the survivors. Stories told from the survivors' side are more common, and an example of this is the web page of the Danish Jews in Theresienstadt (Stræde and Hansen, 2018), where interviews, diaries, and other written memorials are used as sources to tell the stories. A well-told story from a victim's point of view is the Instagram story of Eva Heyman (Kochavi and Kochavi, 2019), which based on her diaries, in video, images, and text, tells the

story of the 13-year-old Hungarian Jew Eva, who was sent to Auschwitz and killed there. Places are sub-categorized into current and past due to the inherent nature of geographical places to undergo changes over time, including alterations in their borders. Many of the locations depicted in the narrative we endeavour to convey exhibited marked differences in their appearance during World War II when contrasted with their contemporary state. an excellent example to combine places into both current and past is the website of the liberation of the Dachau Concentration Camp (Deinert and Maier, 2020), where images of today have an overlay of images from the liberation day.



Figure 15: Vis types

Another significant departure from the original design framework in the context of VBS within the domain of cultural heritage and HNP is that Visual Types can be reduced to three specific categories: maps, timelines, and interactivity. This is because one of these categories constitutes the central and pivotal element in many examples, illustrating how to craft VBS narratives with a particular emphasis on communicating cultural heritage within the context of HNP.

Analysis results

Text is a primary media type regarding conveying information to the end user, but is often supported by secondary types, such as imagery, video, or interactive media, this information is primarily presented as freely explorable, with little narration for the end user to follow. This shows clear precedence for how information commonly is depicted, but the results of this format vary from site to site, this format lets it be up to the end user if they want to engage with the information given instead of immersing them into the material. Based on (Segel and Heer, 2010) it can be seen that to keep the end users' interest they need clear reasoning to be invested, this can be personal stake, engagement through interactivity, or a clear call for action, most cultural heritage sites achieve investment through their subject but struggle to maintain engagement when the user is on the site. To achieve this different usage of the VBS design space that increases immersion and call to action from the end user have a bigger likelihood to succeed. Most sites focus on a personal entity orientation in combination with either locations or events and base these orientations on a matter that is factual. Based on the examples we can see a correlation between the variation of elements from the design space regarding the size of the data sets used on the sites. When handling bigger data sets it becomes more relevant to include different presentation tools for each subject. This is both to ensure a fluent showcasing of both micro and macro environments in the specific data sets and to give a clear visual roadmap for the user to follow. The use of varying elements of the VBS design space ensures that the end user also can take in more information at a given time as seen in (Card, 1999) since their cognitive function is more spread out in contrast to information, given only through one method. There is a clear tendency to depict information through a combination of Synchronic and Diachronic story complexity, the most common usage seen in the survey is either a simple Synchronic approach accompanied by a more complex Diachronic approach or vice versa. The reasoning behind this is to create a balanced experience for the end user, where they can either gather simplified information about many entities or a more in-depth analysis about a few entities.

Future challenges in cultural heritage design space

Based on the findings it can be determined that the extended design space correlates with the survey findings and that the original and extended design space shows the most common usage of VBS in cultural heritage sites. Going forward there is a need to compare the findings of common practices on cultural heritage sites with common trends regarding user interface and user experience. This can be completed by creating Personas of the cultural heritage site target audience and creating design choices that intersect both common practices and target audience specifications. One of the main challenges going forward is how to connect the common trends and practices with the opportunities described in section 2 to elevate how information is currently being communicated to the end user. For this, it is crucial to investigate the outlier examples from the extended design space and find correlations between their usage of the VBS design space with common trends seen in web design and create solutions tailored to user experience.

Conclusion

Institutes of cultural heritage have always been tasked with communicating with the outside world about the significance of history and its memories. In the current era of an ever-evolving media environment, developing an agile design space that can be used and iterated upon as needed is more crucial than ever. Based on reflection on the current visualization-based storytelling design space and the findings made throughout the survey, certain key points can be ascertained, towards the further development of design space implementations for cultural heritage sites. Going forward the extended design space in collaboration with the original VBS design space can give a clear overview of how cultural heritage sites can better communicated with their target audience. Throughout our process we have also spotted several new challenges which gives new perspectives in how to develop and iterate on design practices going forward.

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