



**Cartography M.Sc.**

Master thesis

**Map-based Storytelling  
in Spatial Augmented  
Reality: Projection of  
Interactive Layers**

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# **Map-based Storytelling in Spatial Augmented Reality: Projection of Interactive Layers**

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## **Statement of Authorship**

Herewith I declare that I am the sole author of the submitted Master's thesis entitled:

**"Map-based Storytelling in Spatial Augmented Reality: Projection of Interactive Layers"**

I have fully referenced the ideas and work of others, whether published or unpublished. Literal or analogous citations are clearly marked as such.

Munich, 21/10/20

Nikita Slavin

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## Abstract

Mixed reality technologies are already widely used in the Cultural Heritage field, especially in museums. These technologies have the potential to make an exhibition more entertaining and enjoyable for the visitors. In order to inform the visitor about the displayed exhibition piece or about the event happened, museums often use the storytelling method, particularly with texts, images and videos.

There are currently no conceptual and technical solutions to put a paper map in such a mixed reality environment to tell a story in a museum. Additionally, there is no research investigating if building an interactive environment around the cartographic piece of art could be useful for cultural heritage interpretation.

This thesis investigates how a paper map can be projected and enhanced with interactive layers in such an environment, called Spatial Augmented Reality (AR). Furthermore, this thesis evaluates the impact of this method in the user experience.

In a first step, the hardware and software technology suitable for the realization of an example exhibition was investigated and finally selected. The way of user interactions in the AR space were defined, as well as types of connected media that could be integrated in the exhibition have been explored. Two prototypes have been built using the example of the map of Charles Minard "Napoleon ventured East". One prototype placed the map in a Spatial AR environment, the other one presented the map in a classical exhibition example. Finally, both exhibitions have been evaluated by 25 exhibition visitors within a comparative study. Users have been asked to solve various tasks and comment on their user experience.

The results show that the visitors liked both exhibition samples with a slightly better result of the Spatial AR realization in terms of task solving. The users confirmed that using paper maps in such an environment makes the exhibition more entertaining and is enhancing the museums visitors experience.

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# 1 Introduction

## 1.1 Background and motivation

Digital technologies are transforming all kinds of museums into hybrid and complex spaces, where the virtual lives of characters and stories are blended with the physical form of artefacts (Irace et al., 2013). The design of museum exhibitions and museum experience often uses the storytelling method. Within this method, the visitor is guided through the story, using museum pieces in the interactive and non-interactive exhibit environment. It could create a more comprehensive experience, increase engagement and improve the emotional response (Dal Falco & Vassos, 2017).

Maps can be an instrument of storytelling as well: "it makes information more personal and arrests user's attention to the map" (Mocnik & Fairbairn, 2018). Of course, maps are used in the exhibition design widely, for example as showpieces itself or as supporting materials to other showpieces. However, maps used as a core instrument for storytelling in museums is not common yet. As the author is not aware of any solution where an original map or a reprint is used, this thesis will investigate the possibility and profitability of using printed maps for storytelling in museum exhibitions.

One technology that is widely used in the Cultural Heritage (CH) field is Mixed Reality (MR). Some of these MR solutions are enhancing original historical objects or their replicas by putting them into the interactive virtual environment. This helps to overcome traditional limitations like time, space and non-interactivity (Bekele et al., 2018). The usage of such MR technologies for telling stories via maps could enhance the visitors experience, the quality and the quantity of the acquired knowledge further.

MR techniques, including Spatial Augmented Reality (Spatial AR is AR accessible without any special user devices), are used on three-dimensional objects, giving the possibility to look inside, or show lost parts of it. A popular spatial AR technique is Projection Mapping, a technology that turns the object into the screen. Mixed Reality, mostly Spatial AR solutions, can provide a spectacular effect to viewers by showing insights of historical showpieces using projection mapping techniques. Figure 1 shows an example where Projection Mapping is used to turn the relief model to the interactive map by projecting an image of the map. Additional content (text, photo) is added to the map interface. .

As already mentioned above, there are currently no technical and conceptual solutions to put paper maps in a Spatial AR environment. Additionally, there is no research investigating if building an interactive environment around the cartographic piece of art could be useful for cultural heritage interpretation.

The usage of a map as a core element for storytelling in Spatial AR could give generous dividends, based on the map's high information density and aesthetic. As it is essential to put the user in a comfortable environment with a low entry threshold, Spatial AR techniques seem to have an excellent perspective for the usage as it is accessible without any user's

devices.



Figure 1. Part of the museum of Gorky Park exhibition in Moscow. Projection-Mapping technique is used.

The development of the new method where the user is placed in a Spatial AR environment, could provide museums with a new instrument of exhibition design where the story is told with and by the map. An important part of the method development is finding a balance between the education and entertaining part as the exhibition should tell stories and bring new knowledge and insights. To find that balance, it is essential to compare and measure different approaches for an exhibition design - Classical exhibition and AR exhibition.

## 1.2 Research identification

Within this Master's thesis, the applicability of the Spatial AR technology for Map-based storytelling exhibitions should be investigated. The current practice of using maps in exhibitions in most cases involves one of the following two methods: (1) traditional non-digital expositions or (2) digital copy showed with the screens or projections.

There is a research gap in these two methods. There are currently no solutions known where the printed map is exposed within the digital environment.

### 1.2.1 Research objectives

The main objective of this thesis is to propose and evaluate a method of Map-based storytelling in Mixed Reality in order to enhance the user experience.

This overall objective can be divided into four sub-objectives:

- I. Make an overview of current MR technologies for CH. Identify the most common limitations of classical exhibitions and ways to avoid them.
- II. Chose the technologies that can be used for the projection of interactive layers on the map.
- III. Find the ways of user interactions with maps in AR-space. Figure out what kinds of connected media and information could be integrated into the exhibition.
- IV. Evaluate the proposed method concerning its impact on the user experience.

### 1.2.2 Research questions

To reach the four research objectives and to provide the structure for the method development and evaluation, the following research questions need to be answered:

- I. Which MR methods are used in CH applications, especially in exhibitions, how do they guide user through story? What are the limitations of traditional exhibition methods while storytelling using maps and how to overcome them?
- II. How can the projection of interactive layers on printed historical maps in a Spatial AR environment be realised?
- III. How can users interact with a paper map in the Spatial AR environment? What kinds of connected media and information can be added? Furthermore, how can it be realised for different types of media (e.g., are there differences)?
- IV. Can the new method make storytelling using maps more enjoyable/entertaining, and enhance the user experience and quality and quantity of the acquired knowledge?

### 1.3 Innovation aimed at

A new method combining printed maps and Spatial AR will be proposed, filling the gap between non-interactive and fully digital solutions.

The hypothesis is that the proposed Map-based storytelling in Mixed Reality method could enhance the user experience: the way of the story exploration will become more entertaining and flexible, and as one of the results, the quality of acquired knowledge will be better than with traditional solutions.

The proposed method (solution) could find a field of usage in all kinds of museum exhibitions and various educational projects.

### 1.4 Outline of the thesis

The thesis is divided into six chapters. In the first chapter, background and motivation are given, research objectives and questions are defined. The second chapter provides an



overview of state of the art in related topics: MR techniques for CH, MR and maps, usage of AR in exhibitions and storytelling with maps. The third chapter is introducing the Minard map and its different interactive and non-interactive interpretations: books, posters and web-applications. The Minard map will be used for the case study and two different exhibitions will be developed. The research approach and the methodology, including AR and Classical exhibition prototypes development and the key aspects of the user evaluation are described in the fourth chapter. The results and their discussion are presented in the fifth chapter, that is followed by the conclusions and outlook for future research in the sixth chapter.



be repeated recursively. However, different studies show different approaches to the structure of the stories and storytelling design. Roth (2020) for example follows Lee's approach, but suggests to divide a story into a linear three-act spatial narrative and names this "setup-conflict-conclusion". Within this thesis, the story build in both exhibitions will follow Roth's and Lee's suggestions.

### 2.1.1. Storytelling in museums

The usage of the storytelling method in modern museums is closely connected to the usage of modern technologies, including AR, VR, and MR technologies.

Ahmed et al. (2014) argue that exhibitions in museums should be designed to communicate ideas. This communication is done primary through visual senses (Ahmad et al., 2014).

According to Dal Falco & Vassos (2017), the aim of using modern technologies in Museum Design is to achieve an integration between the museum goods and the content inside of them. Thos could be done with new forms of technology-based narrative experiences (Dal Falco & Vassos, 2017).

Dal Falco & Vassos (2017), proposing a new paradigm of Museum experience design, facilitating traditional communications methods with a new type of interaction. They are calling it Storytelling experience. It is underlined that museum experiences require broader lifecycle, involving visitors before and after their visit using different ways of communication.

Serota (1996) is discussing the changing role of the visitors in modern museums. While interacting with the artefacts, visitors gaining first-hand participating experience and integrating themselves with performances and events.

Digital technology is transforming museums into hybrid and complex spaces, where the virtual lives and characters and stories are blended with the physical form of artefacts (Irace et al., 2013). Dal Falco and Vassos (2017) see museum artworks as an instrument for the live storytelling experience, which could get benefits from technology-driven design. The story is specified and managed by story points, tracing the development step-by-step. The approach is similar to videogames. Similar personalised stories and adventures are applying to create interactive narratives for the museums.

The usage of the storytelling approach and cutting-edge digital technologies in museums can bring rich dividends. It is important to be careful and don't let the form take precedence over the content.

### 2.1.2. Storytelling in and with maps

Within this chapter it will be investigated how maps can be created and designed to tell stories, how maps can be a part of a storytelling narrative or how maps can be a storytelling narrative by itself.

The paper “Maps Telling Stories?” (Mocnik & Fairbairn, 2018) is comparing texts and conventional maps as instruments for storytelling. Mocnik & Fairbairn are coming up with a new concept of map design for storytelling. They are underlining that “maps are far worse in telling stories” compared to the text, because they have different functionalities and affordances. Another essential point in the context of this study is that often a story is not part of the map. The authors are coming up with elegant solution to integrate it as it is seen on the fig 6 (g-j).

In this thesis, different types of contents are going to be used. That’s why it is important to compare two of the most common storytelling elements: texts and maps. Text and maps are very different instruments for representing landscapes. Map representations despite all its advantages have a lot of limitations: of scale, symbology, classification and categorisation, interactivity. It is fascinating to compare maps with text representations of the same landscape. Mocnik & Fairbairn using the example of a text extract from Silt Macfarlane (Macfarlane, n.d.) about his walk in the area in Essex, England:

“The air was grainy and flickering like an old newsreel. The sea wall had hazed out to a thin black strip. Structures of unknown purpose – a white-beamed gantry, a low-slung barracks – showed on the shoreline. [...] The light had modified again, from nacreous to granular to dense. Sound travelled oddly. The muted pop-popping of gunfire was smudgy, but the call of a cuckoo from somewhere on the treeless shore rang sharply to us. A pale sun glared through the mist, its white eye multiplying in polls and ripples. The miniature sandscapes of ridge and valley pressed into the soles of my feet [...]”

According to Mocnik & Fairbairn (2018) there is no way to the conventional topographic map shown in figure 4 evoke similar emotions while telling the same story like told with text above.

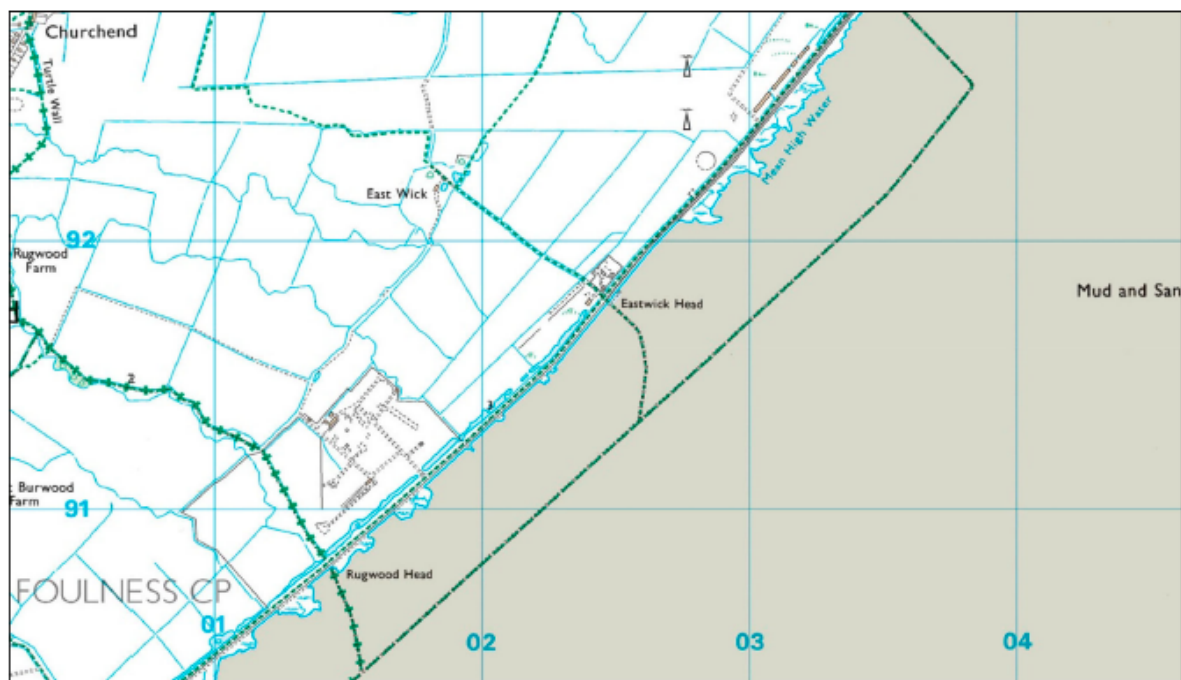


Figure 4. Topographic map representation of coastal mud flats, Essex, England (grid interval 1 km). Ordnance Survey (Digimap Licence), taken from(Mocnik & Fairbairn, 2018)

In their work, Mocnik & Fairbairn (2018) are proposing a new approach for storytelling using maps the "story focus". The story focus is a variable generalisation technique, which is adapting a story in the map via variation of the content, levels of detail, scale, precision and uncertainty, and other parameters. The approach is shown in Figure 6.

In the thesis different types of content will be integrated in the storytelling using the map as a core element.

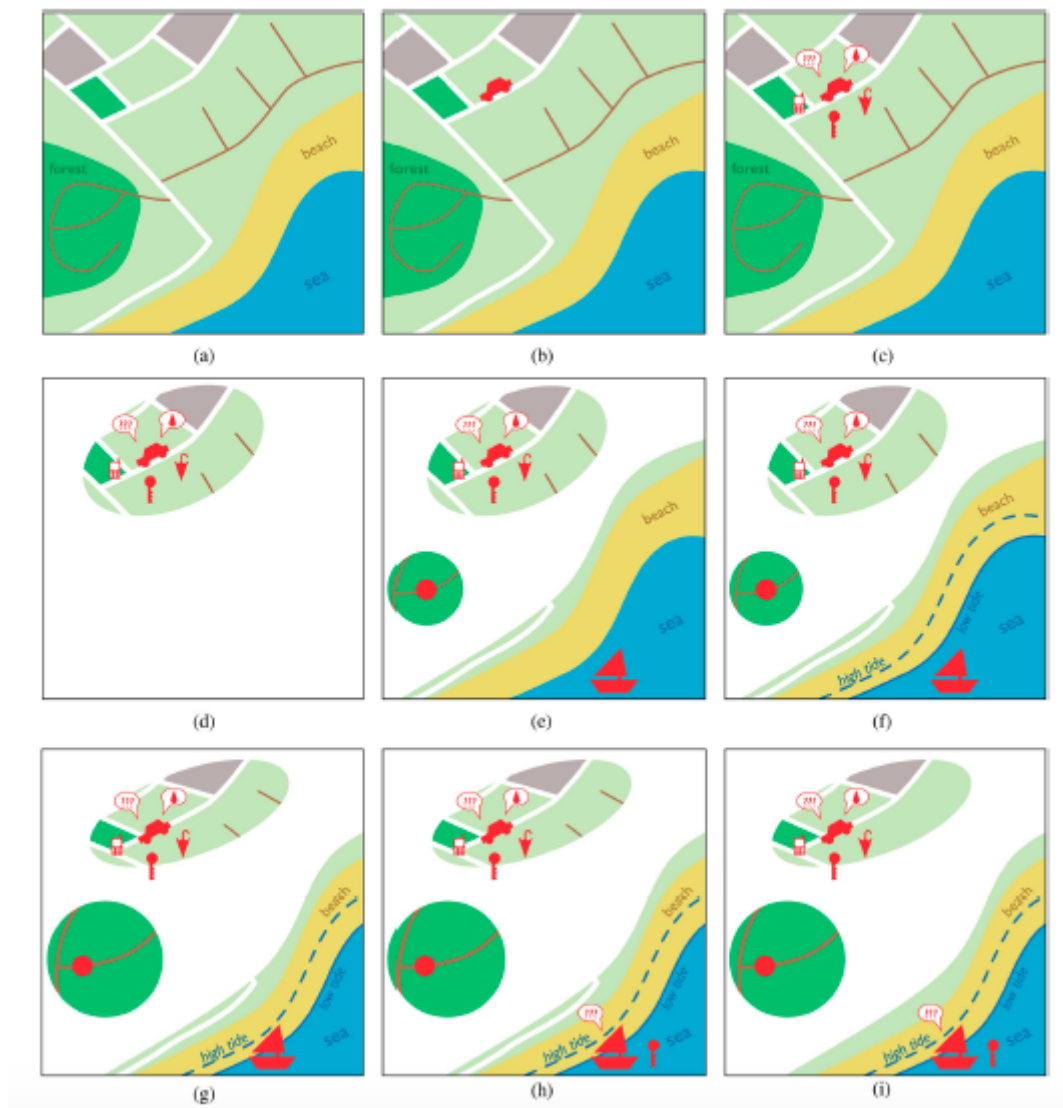


Figure 5. (a)map; (b) map and character; (c) map, character, and non-spatial data, (d) character's surroundings; (e) several character's surroundings; (f) adding time; (g)-(i) different scales are used to highlight different objects. Figure taken from Mocnik & Fairbairn (2018).

Maps are the storytelling instrument. Many researchers agree that the famous Charles Minard map of Napoleon's army in the Russian campaign 1812 is probably the first

storytelling map (see figure 5). The case study of the thesis is based on this map. The map, its history and content will be described in detail in the next chapter 3.

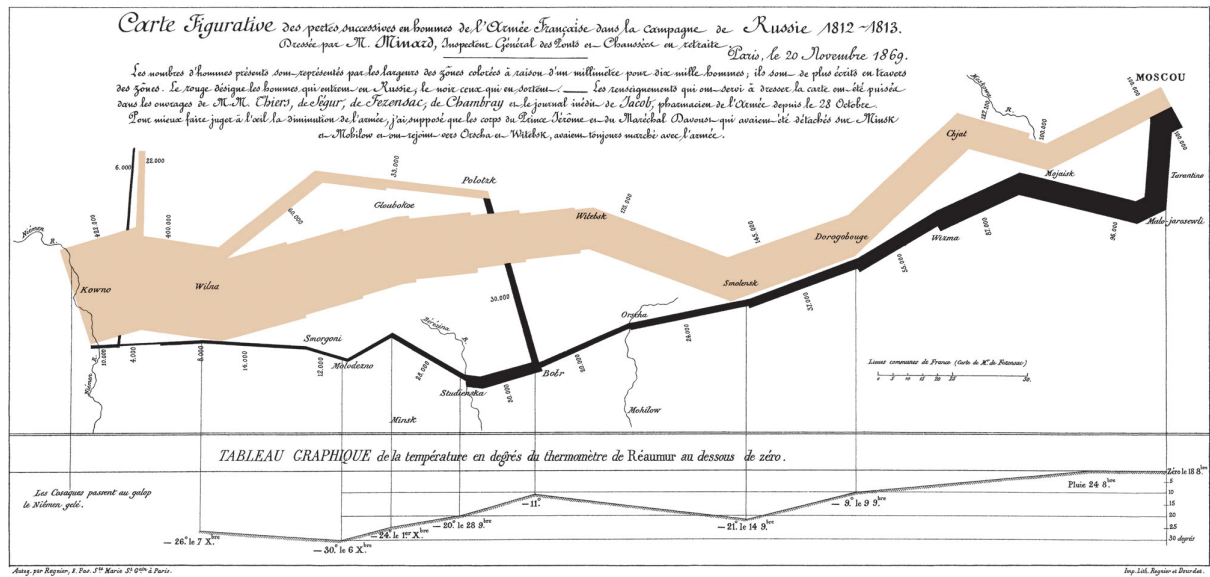


Figure 6. Map of Napoleon's Russian Campaign by Charles Minard, first published in 1869. [Taken from: https://commons.wikimedia.org/wiki/Main\\_Page](https://commons.wikimedia.org/wiki/Main_Page)

## 2.2 Mixed Reality for Cultural Heritage

The studies in the field of Augment, Virtual and Mixed Reality for Cultural Heritage are part of a broader field called "Cultural Computing". According to Fei-Yue Wang (2009) Cultural Computing (CC) is "an emerging field that applies computer technology and scientific methods to culture, arts and the social sciences to represent, enhance transform creative products and processes".

CC is used for analysing, studying, preserving and visualising CH assets (Gonizzi Barsanti et al., 2015). The rapid development of IT technologies involves immersive technologies in the CH field (Bekele et al., 2018).

The reality-virtuality continuum proposed by Milgram & Kishino (1994) makes the distribution and hierarchy of the terms Mixed Reality (MR), Augment Reality (AR), Augment Virtuality (AV) and Virtual Reality (VR) clear (see figure 7). Spatial AR, which will be studied in this thesis, is positioned between AR and AV in this continuum.

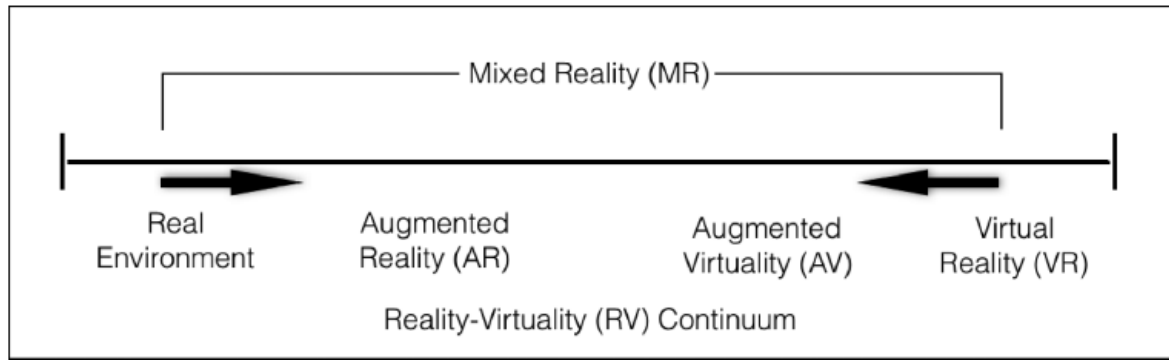


Figure 7. The reality-virtuality continuum consists of environments ranging from real to virtual and all possible variations and compositions of real and virtual objects in these environments. Taken from: IEICE TRANSACTIONS on Information and Systems (1994).

In a comprehensive review of MR technologies for CH Bekele et al. (2018) gives the following definitions for this scope of terms:

- Mixed Reality: aims to combine real and virtual environments.
- Augmented Reality: adding the virtual layers to the user's view of the real world.
- Augmented Virtuality: is a virtual world is augmented by the real world.
- Virtual Reality: fully virtual experience

Bekele et al. (2018) (highlight the following essential aspects of AR, VR and MR applications:

- Tracking and registration
- Virtual environment modelling
- Computers, display, and devices for input and tracking
- Interaction interfaces

The classification for tracking and registration methods, displays and interaction interfaces by Bekele et al. (2018) are represented in Table 1 below. The information collected in it will help to choose the right software and hardware technologies stack for the exhibitions later on. This thesis will focus on Spatial AR solutions: the AR solutions using the same name displays, which are providing access to the Mixed Reality without any user's devices. More specifically, it is planned to develop a Spatial AR solution that is using a camera-based, markerless tracking system, a hybrid Spatial AR and desktop projection display with a hybrid interaction interface.

Tracking and Registration		Displays		Interaction interfaces
Camera-based		Head-mounted display	AR, VR	Tangible
	Marker-Based tracking	Spatial AR displays	AR	Collaborative
	Markerless tracking	Hand-held devices	AR, VR	Device-based
	Infrared Tracking	Desktop screen and projection	AR	Sensor-based

Sensor-based	CAVE (Cave Automatic Virtual Environment)	AR	Hybrid interfaces
Electromagnetic tracking			
Acoustic tracking			
Inertial tracking			
Hybrid tracking			

Table 1. Tracking and registration methods, displays and interaction.

Most of the papers (e.g. Fei-Yue Wang , Gonizzi Barsanti ) agree in significant value added to CH objects by the usage of the immersive reality technology stack. However, many researchers point to the danger of technologies become the first order of visitor attention, and art to the background ( Cameron & Kenderdine, n.d.). The MR solutions for CH can provide education, exhibition enhancement, exploitation, reconstruction and virtual museum functions (Bekele et al., 2018).Pierdicca et al. (2016) are worrying about a trend towards “the show and glamour of innovation” and think that this trend will prevail on the decision of exhibition tasks.

Most of the studies in the Spatial AR field are based on real cases like exhibitions projects around outstanding artefacts, software and hardware solutions.Spatial AR could be realised as a projection on two-dimensional or three-dimensional objects. It allows users to explore hidden insights or narratives of the artefacts (Basballe & Halskov, 2010). A vivid example are the interactive projections on the Mejlby stone at the Kultur Historisk Museum in Randers, Denmark (see figure 8 ). This solution engages the communication process, shows the history of the stone, involves visitors in a game to explore the object. The traditional solution assumes communication via the small exhibition labels placed beside the stone. That is obviously not so easy in terms of perception but an attractive Spatial AR solution.



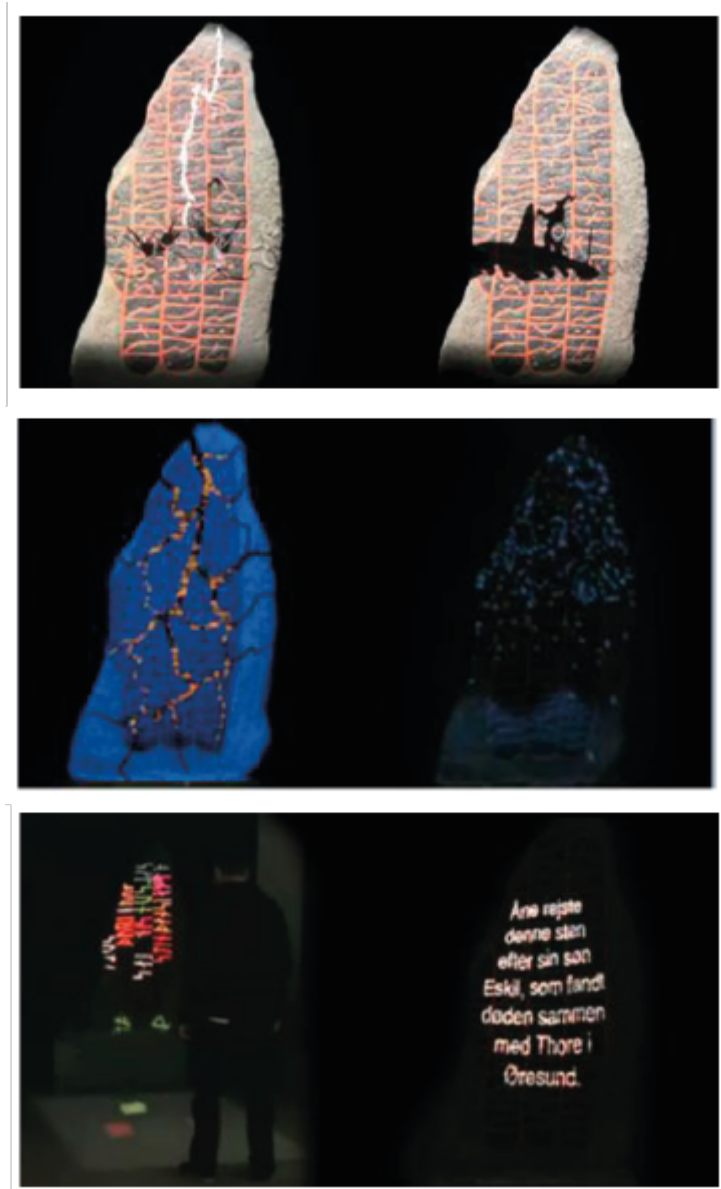


Figure 8. The Mejlby stone exhibition.

A noteworthy solution of Spatial AR on a two-dimensional screen surface is proposed by the Resee Muntean (2015) in the paper “?eləwk– Belongings: A Tangible Interface for Intangible Cultural Heritage.” ‘The tabletop uses replicas of Musqueam belongings excavated from cəsnaʔəm, as well as contemporary objects that are a part of everyday Musqueam life to access information about the long history of salmon fishing and the continuity of related knowledge at cəsnaʔəm.’ (Muntean et al., 2015). This approach allows to overcome the limitation of an exhibit space, showing the digital copies of items and its replicas and at the same time realising interactions with the original objects. The interface is shown in Figure 9 below.



Figure 9. Țelăwk<sup>w</sup> – Belongings (Courtesy Reese Muntean).

The good design of a museum exhibition will use a wide range of traditional and innovative solutions in order to create the best visitor's experience. The prototypical exhibition "Macedonia from fragments to pixels" comprises seven different interactive systems. Within this thesis, the particular interest is in the "Multimodal diverse travel" item: In this exhibition, the table is covered by a printed map. The map is blank and different kind of the data are projected on it as well as a brief bilingual instructions. (Grammenos et al., 2013) The system is multiuser and allows interactions with cardboards. Users can explore different kinds of related content.

In the next chapter the technology stack for the Spatial AR environment design will be investigated. The choice will be based on the aforementioned studies.

## 2.3 Mixed Reality and maps

The definition of a map in cartography is changing because technologies are changing our world and everyday life. Printed maps, as well as printed photos, are in more and more rare everyday use (Werner, 2018). Within this transition period from printed to digital media, different MR applications with maps are also arising: Reality augmented with maps, maps augmented with mixed reality. There are different ways to access this MR with/or without user's devices, online and offline. A potential combination of the properties of printed maps with virtual information could combine the best of both real and virtual worlds. AR can 'boost' paper maps with modern digital technologies (Pereira et al., 2017).

The thesis specific interest is in paper maps in Spatial AR solutions. It seems like works in this topic are rare and practice-oriented. For example, Reitmayr (2005) proposes in his work a way of augmenting paper maps via the projection of new layers, as a controller. Either a PDA device is used or a cardboard with a projection on it (see figure 10).



Figure 10. An augmented map, showing the flooded River Cam.

Another example is a tourist map proposed by Norrie & Signer in 2005. After “clicking” on the map, a paint pen provides audio information (see figure 11 ).



Figure 11. Edinburgh Festivals System.

There are no more recent examples of putting maps in Spatial AR about that author is aware of. It seems a promising topic for research that could contribute to the field of cartography.

### 3 Data Description for case study

The third chapter will give a brief introduction to the map that will be used as a core element for the prototype storytelling exhibitions. The map itself and the related studies background, as well as modern interpretations of the map will be presented; after the process of data preparation and processing will be described.

The Charles Minard "Napoleons" map is enjoying longstanding fame in both cartography and statistics (Kraak, 2014). Some call it "the first data visualisation", others "the first example of the storytelling" (Rendgen, 2019). The map has its pros and cons, is very well studied and has a lot of interpretations. There are a lot of digital materials about the map available (scans, websites, databases). The story the map tells is dramatic. All these points indicate that the map is perfectly suited as case study for the research conducted within this thesis.

The full name of the map (translated from French) "The Figurative Map of the successive losses of men of the French army during the Russian Campaign 1812-1813" is placed on the top of it (see figure 12). The map was first time published in 1869 and has a now-forgotten map sibling about Hannibal's Italian campaign in 218 BC during the Second Punic war (figure 12). Both maps are showing losses of armies during the campaign and use the same cartographic language. In cartography these works fall in the category of flow line maps (Kraak, 2014). The size of Napoleon's campaign map is 63\*25 cm. The labels are given in French, main colours are black and specific "brown" colour, which causes discussions among researchers.

Despite a large number of studies that have been made about the map, the map is still quite popular: from the authors experience almost in every university course involving topics related to cartography, statistics or infographics, this map appeared. In his book "Mapping time" Kraak (2014) studied a complicated task of showing time on maps and infographics using the Minard Map as example. It is important to notice that the map is not only one that was created by Minard. Interested readers will find all his graphical works in the book "The Minard System: The Complete Statistical Graphics of Charles-Joseph Minard" by Sara Rendgen (Rendgen, 2018).

Additionally, the number of modern interpretations proofs the popularity of the map. Minard's map is available for order as a poster today, moreover reinterpreted patterns are used for different merchandise from mugs to T-shirts. The last are shown in figure 13 (Rendgen, 2019).

Kraak (2014) emphasises some shortcomings of the Minard's map:

- The exact time references rarely occur.
- Map express the disaster, but not why it's occurred. The temperature graph tends reader to make cold was a reason. But an inquisitive reader will notice that there is no direct connection between temperature and loses.



- This thesis is another contribution that tries to overcome the shortcomings of the map using a modern technology. The shortcoming will be kept in mind during the design process. The web interpretations described below have already shown that these problems are solvable and significantly increased the value of storytelling. This research will make a interpretation of the storyline based on the printed map.

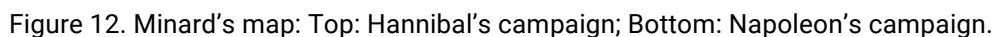




Figure 13. Minard inspired T-shirts Source:  
[https://www.zazzle.com/charles\\_minard\\_in\\_black\\_t\\_shirt-235775886405738885](https://www.zazzle.com/charles_minard_in_black_t_shirt-235775886405738885).

In the paper “Re-Visions of Minard” in 2012, Michael Friendly draws the reader's attention to other works of Minard and tells his personal story of its exploration. He also describes some digital interpretations of Minard's Napoleon map (Friendly, 2002). On Friendly's website <http://www.datavis.ca/gallery/re-minard.php> the basic dataset and different recreations of the map are presented. Most of them are dated the 2000s, but still entertaining.

Taking a look into more modern web-interpretations of the map, these interpretations are enhancing the maps' functions by adding interactivity. An interactive chart by “mass:werk” studio (<https://www.masswerk.at/minard/>) shows the translations on hover, adds a slider which helps to track the number of troops in armies, dates and temperature. The map and these indicators are shown in figure 14.

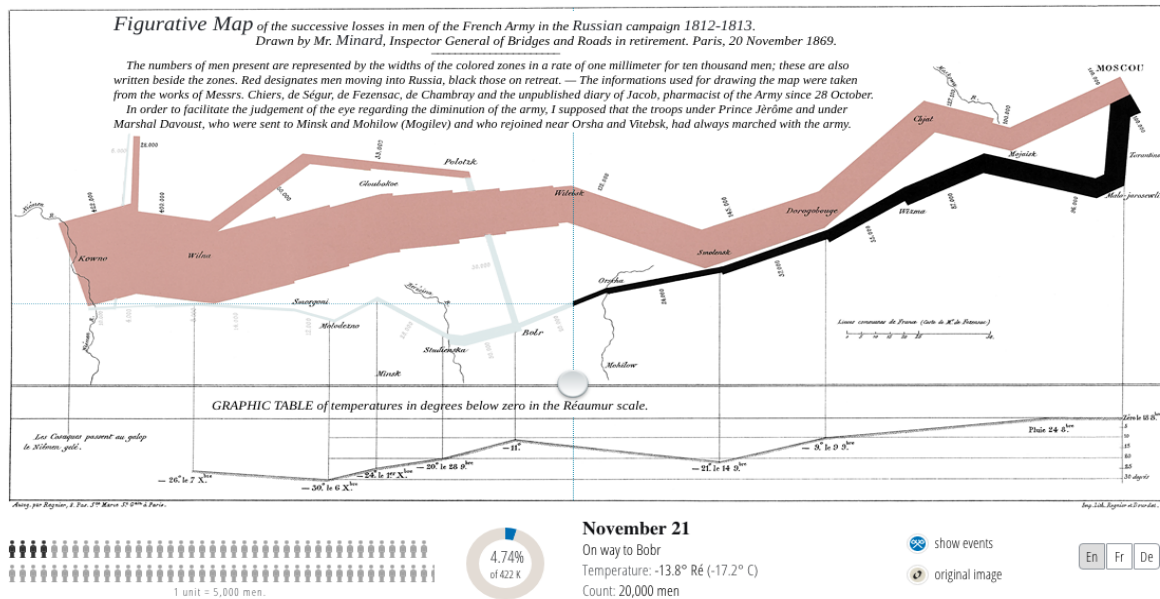


Figure 14. An interactive chart by the mass:werk (Mass:werk, 2020)

The storytelling project “When Napoleon Ventured East” by the Russian news agency “TASS” (<https://1812.tass.ru/en>) is a deep revision of the original map. The map is recreated as a set of 3D bar charts with the height corresponding to the number of troops at the specific moment. The web browser screen is divided into two parts: On the left is an interactive map, on the right is a richly illustrated article telling the story (see figure 15). Both parts are synchronized: the map on the left is showing the moment that is described in the text on the right. Some additional information like location and distribution of forces is added at the start of the story or points of important battles.

With the permission of the TASS Agency, the storytelling text, some illustrations and graphic elements will be used for the case study exhibitions created within this thesis.



Figure 15. “When Napoleon ventured east” project” (TASS, 2020).

The structure of the story used as case study example follows the narrative by the TASS agency. For the prototype design, the following data were collected and processed (Table 2):

Data	Source	Link
Vectorized and georeferenced original Minard map	NEH workshop on digital methods for military history	<a href="https://web.north-eastern.edu/nulab/dmmh/">https://web.north-eastern.edu/nulab/dmmh/</a>
Georeferenced points of main battles and events	NEH workshop on digital methods for military history, TASS	<a href="https://web.north-eastern.edu/nulab/dmmh/">https://web.north-eastern.edu/nulab/dmmh/</a> ; <a href="https://1812.tass.ru/">https://1812.tass.ru/</a>
Borders of alliances and army's distribution	TASS	<a href="https://1812.tass.ru/">https://1812.tass.ru/</a>
Day by day information about troops amount	multiple	
Main events by the dates	multiple	
The geographical position of the army by the date (the connection between map polygons and the dates)	multiple	

Table 2. Data and data sources



## 4 Methodology and conduct of the research

The fourth chapter will describe the research methodology chosen to distinguish the thesis goals. After that, the case study maps and applications will be represented in detail. As defined in the thesis introduction, the main goal is to propose and evaluate a method of Map-based storytelling in Mixed Reality in order to enhance the user experience. The case study will test the method on the example of Napoleon's Russian Campaign and Minard's map, describing it via map-based infographics.

### 4.1 Chosen research approach

The overall research approach is schematically shown in the figure 16 and consists of literature review, method concept, exhibition prototypes realisation. Two prototypes will be created in order to conduct a comparative study/user evaluation. One prototype will be built in a MR environment. Another prototype will be created and designed in a classical exhibition scene.

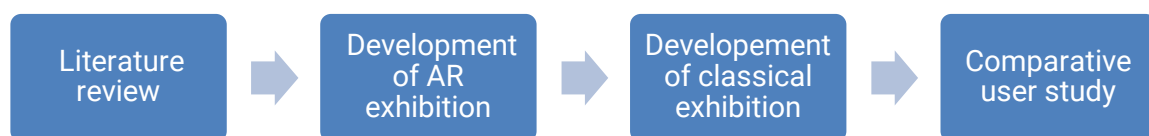


Figure 16. Research workflow

#### 4.1.1 Concept of the exhibitions

In the second chapter in table 1, tracking and registration methods, displays and interactions are listed. The table is the basis for choosing the exact MR technology for the realization of the exhibition prototype and implementing the MR method in order to reach the stated research objective.

The goal of telling a map-based story in Spatial AR will be reached by putting the Minard map of Napoleons campaign into the MR environment. The map as peace of art should be valued and it is therefore important to highlight it and build an exhibition around the map itself.

In order to enhance the user experience, "the user entry threshold" should be as low as possible: an exhibition visitor should not have to use any devices and learn how to work with it. The attractiveness of the exhibition itself should be increased by adding a magic "wow" effect to the exhibition.

The above-mentioned requirements define the following choices (table 3):

Type of MR	Spatial AR
Tracking and registration	Any markerless solution
Display:	Desktop screen and projection
Interaction interfaces	Sensor-based

Table 3. MR solution description.

Spatial AR is the solution which doesn't use any user devices. Markerless tracking and registration methods follow low threshold requirements. The maps are mostly printed on paper. They are flat.

The classical way of showing maps in exhibitions is putting the map on the wall or on the table, sometimes in the horizontal showcase (figure 16). Because the user wants to interact with the map and its surroundings, the solution in this case is often to put the map on a table. Putting the printed paper map on a table and overlay it with an interactive projection seems finally reasonable. That is the main reason why the desktop screen and projection as display type is proposed in this thesis.



Figure 16. Cartographic British Library exhibition design by the Northover & Brown (<https://www.designweek.co.uk/issues/5-11-december-2016/cartographic-british-library-exhibition-places-visitor-map/>).

As seen from the related studies, a wide range of technologies could be used for museum exhibitions. The selected Spatial AR solution as well could be realised in different ways. For the method, mass and affordable solutions were chosen, that will help its replicability and usability. The hardware setup is shown in figure 17.

The Spatial AR is created on the surface which is an intersection of the image projected on the table with a map by using an ultrashort distance projector and the field of view of the depth camera. The printed map is in Spatial AR and could be enhanced by interactive projection or become a part of the interface.

The ultrashort distance projector is turning the table surface into the screen. There is a wide range of projectors on the market the hi-end models could project a HD picture with high geometry quality even in bright lighting conditions. However, no market analysis is part of this research. The ultrashort distance beamer available will be used for the prototype.

Kinect cameras are used as markerless tracking and registration devices. They are providing RGB and depth (distance to points in a field of view from camera sensor) images. Kinects are widely used in interactive museum exhibitions. There are developer's kits and ready to use software available.

An alternative to the depth camera would be touch tracking systems integrated to the projectors by their manufactures.

There are some aspects of design a specific implementation that could radically change the perception of the exhibition: the hardware could be easily hidden in the wall, so the devices are invisible for the user. The height of the table should be comfortable for all user groups or stand should be presented. If the exhibition is activated, means a person is appearing in the field of view of the sensor, it can have an interesting magic effect: it becomes alive as soon as a visiting person starts any interaction.

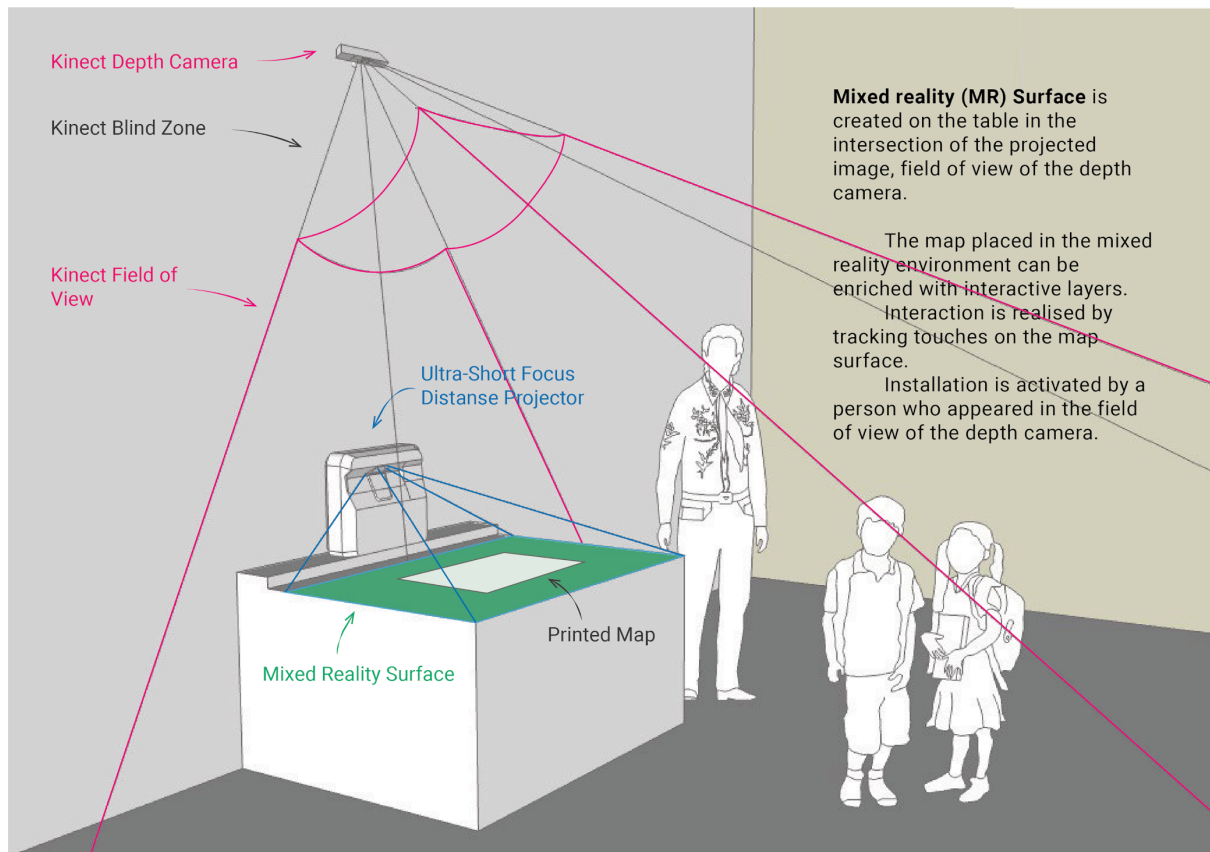


Figure 17. Hardware setup concept.

The storytelling with and in maps, of course, should use all kinds of media to tell the story. Each story needs its own set of tools and user interface in order to be heard by the maximum number of souls. The AR application development platform for the method should give the designer this flexibility of media integrated and user interface design.

The most common types of media that could be used in the AR application, according to the studies about storytelling, are:

- Texts
- Pictures and graphics
- Audio
- Videos and animations
- Maps

The storytelling conception could be different: the long read, story-focus map, a game, or timeline and etc. The chosen conception and the content will define the graphical and interface design.

The map becoming the core element in telling a story. To become the core, it could be overlaid with other maps. These maps can be static or dynamic, with the same extent or at the same time they can also be extended to the table surface. These overlaying maps could be different for each part of the story. The designer could create as many overlays the story needs.

The Unity cross-platform game engine for the AR application will be used within this thesis. It provides the requested content and design flexibility, uses common C# language and has visual coding add-ons. The licensing is free for personal use or small companies, which is certainly an advantage.

#### 4.1.2 Evaluation of the exhibitions

As mentioned before, a prototype of an AR exhibition will be developed within this thesis using the proposed method. The case study will tell the story of Napoleon's Russian Campaign with Charles Minard's map. The main user interface element integrated will be a timeline. Media types that will be used are maps, texts, graphics and a background sound.

In order to evaluate the method in terms of efficiency, effectiveness and satisfaction, a classical version of the exhibition will be created. The classical exhibition will tell the same story, with the same content, but no digital technologies will be used. The test user group will be divided into two equal parts: one group will work with the AR exhibition; the other group will work with the classical exhibition. The study aims to find strong and weak elements of each solution and compare both solutions from practical and user experience sides.

Both exhibitions are displayed in the same room under the same conditions. Participants are invited to visit the exhibition and giving feedback. During the user test, the participants can ask questions or can get help when needed. The study is monitored. The time needed to answer each question about the story, as well as self-exploration time and notes are recorded by the experimenter.

After the introduction and filling the personal data into the evaluation form, the users are asked to self-explore one of the exhibitions. Afterwards, participants will be asked to answer questions about the story that has been told. While answering these questions, users are allowed to interact with the exhibition. Finally, experience feedback without access to the exhibition will be collected.

The proposed experiment design allows comparing two approaches: AR and classical. Thus, the proposed method will be evaluated. However, the experiment is limited to the selected story; it's content and associated media.

#### 4.2 Conduct of the research

The research is divided into three parts: Development of (1) AR and (2) Classical versions of the Minard map exhibition and (3) evaluation.



### 4.2.1 AR exhibition development

As explained in chapter 4.1, the method's hardware and software stack were selected. The specific implementation on the example of the Minard map will be described in the following.

#### Hardware setup

For the study, the following hardware was available:

- NEC NP-U310W projector
- Kinect for Windows v1
- White table 80\*115\*70(H) cm

The draft hardware setup with the calibration grid is shown in figure 18.



Figure 18. Hardware setup.

The specifications for NEC NP-U310W, a 3100-lumen widescreen ultra short throw projector, released in 2011, are shown the figure 19. The projector is quite old and cannot provide the HD resolution; however, it has all the necessary characteristics to realize the AR exhibition prototype.

## Product Specifications

### Display

Aspect Ratio	16:10	Native Resolution	WXGA 1280x800
Maximum Resolution	UXGA 1600 x 1200	Contrast Ratio (typical)	2000:1

### Synchronization Range

Horizontal (Analog/Digital)	15-91.1 kHz	Vertical	50-120 Hz
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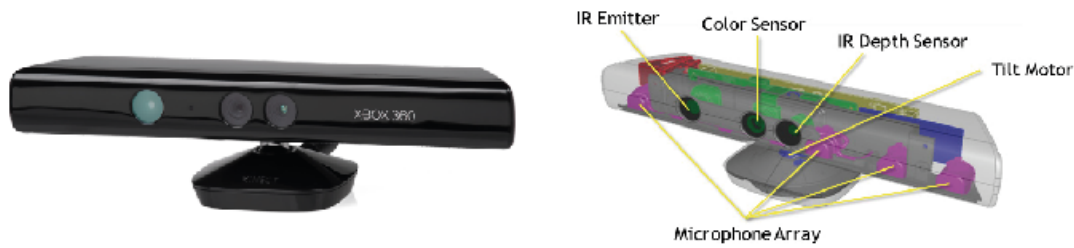
### Signal Compatibility/Connectivity

Supported Video Standards	NTSC, NTSC443, PAL, PAL-M, PAL-N, PAL-60, SECAM	SD/HD Video Signal Compatibility	480i, 480p, 576i, 576p, 720p, 1080i, 1080p
PC Signal Compatibility	VGA, SVGA, XGA, WXGA, WXGA+, SXGA, SXGA+, UXGA	Macintosh Signal Compatibility	Yes
Sync Compatibility	Separate Sync / Composite Sync / Sync on G	External Control	RS-232, IR, Wired LAN, USB

<b>Input Terminals</b>		<b>Output Terminals</b>	
RGB1(analog):	VGA 15-pin D-sub, Component video using ADP-CV 1E	Audioout:	Yes (variable)
RGB2(analog):	VGA 15-pin D-sub, Component video using ADP-CV 1E	Monitor Out:	VGA 15-pin D-sub
RGB3(digital):	HDMI		
Video 1:	RCA		
Video 2:	S-Video		
Audio 1:	1/8 in. stereo		

Figure 19. NEC NP-U310W technical specifications.

The Kinect camera is RGB-D camera, which can detect and track users and their movements. It will be used as an input device with the software “Touchless touch”. The projection becomes a touchscreen if it is in field of view of camera and pre-calibration is executed. The camera, it's equipment and specifications are shown in figure 20.



Kinect	Specifications
Viewing angle	Field of View (FoV): 43° vertical x 57° horizontal
Vertical tilt range	±27°
Frame rate (depth and color stream)	30 frames per second (FPS)
Audio format	16-kHz, 24-bit mono pulse code modulation (PCM)
Audio input characteristics	4-microphone array 24-bit analog-to-digital converter (ADC) onboard signal processing (including acoustic echo cancellation & noise suppression)
Accelerometer characteristics	2G/4G/8G accelerometer configured for 2G range 1° accuracy detail limit <i>(can help detect when the sensor is in an unusual orientation)</i>

Figure 20. Kinect camera, hardware and specifications.

The size of the table (80\*115\*70(H) cm) that was used for the prototype was chosen carefully: the aspect ratio is almost 16:9 which allows you to use the maximum area for projection.

It is needed to evaluate the preciseness of the touch tracking of the prototype hardware setup. In order to do that the calibration was executed: the mesh with a grid size 5 cm was projected, each touch to the grid centre was traced by a line on the screen. The calibration setup is shown in the Figure 21.

Figure 22 shows the results of the calibration. The dependence of accuracy on the location of the sensor is clearly visible. Most of the traces are within the cells and consequently defines the size of the element of the future interface: 5 cm. The usage of this size will guarantee the uniqueness of response of interface elements and satisfaction from its work.



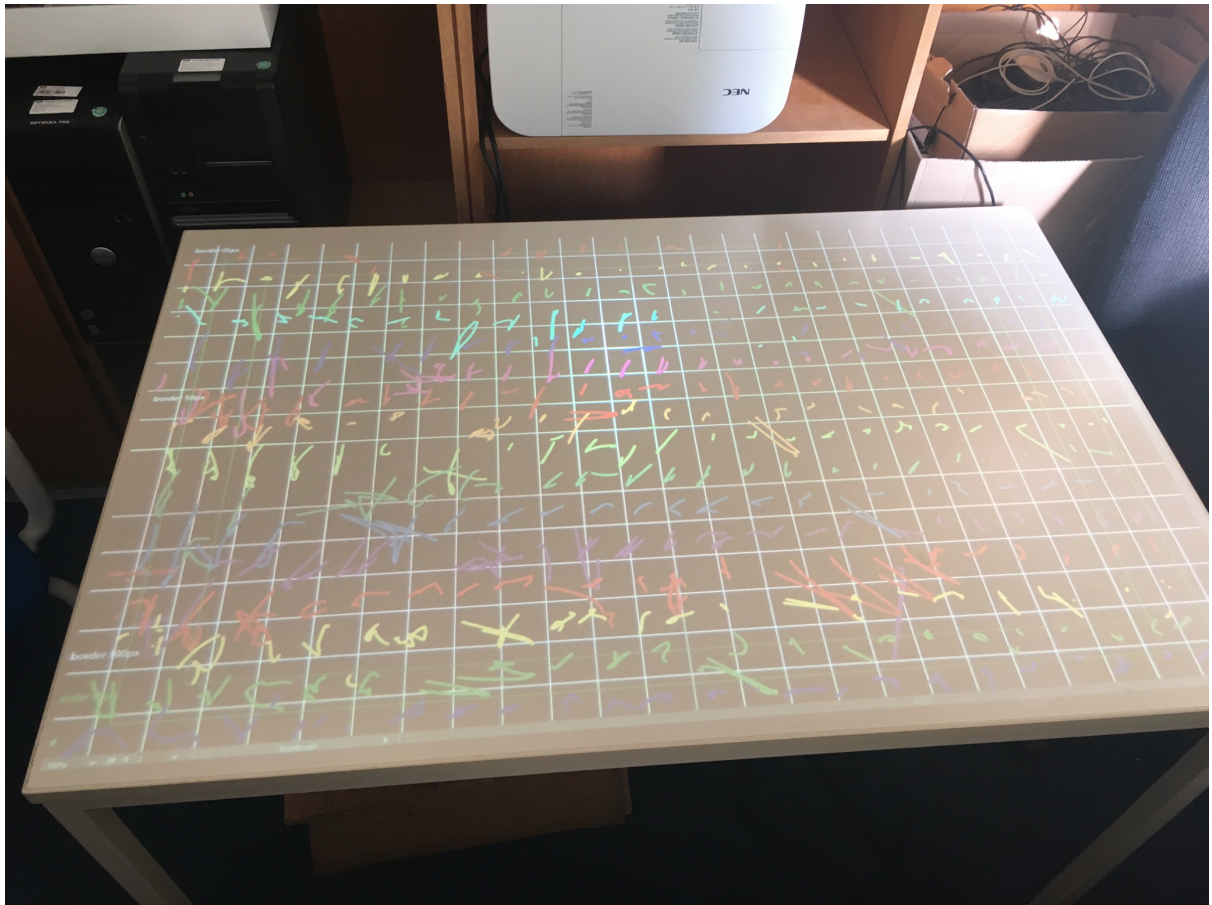


Figure 21. Calibration setup.

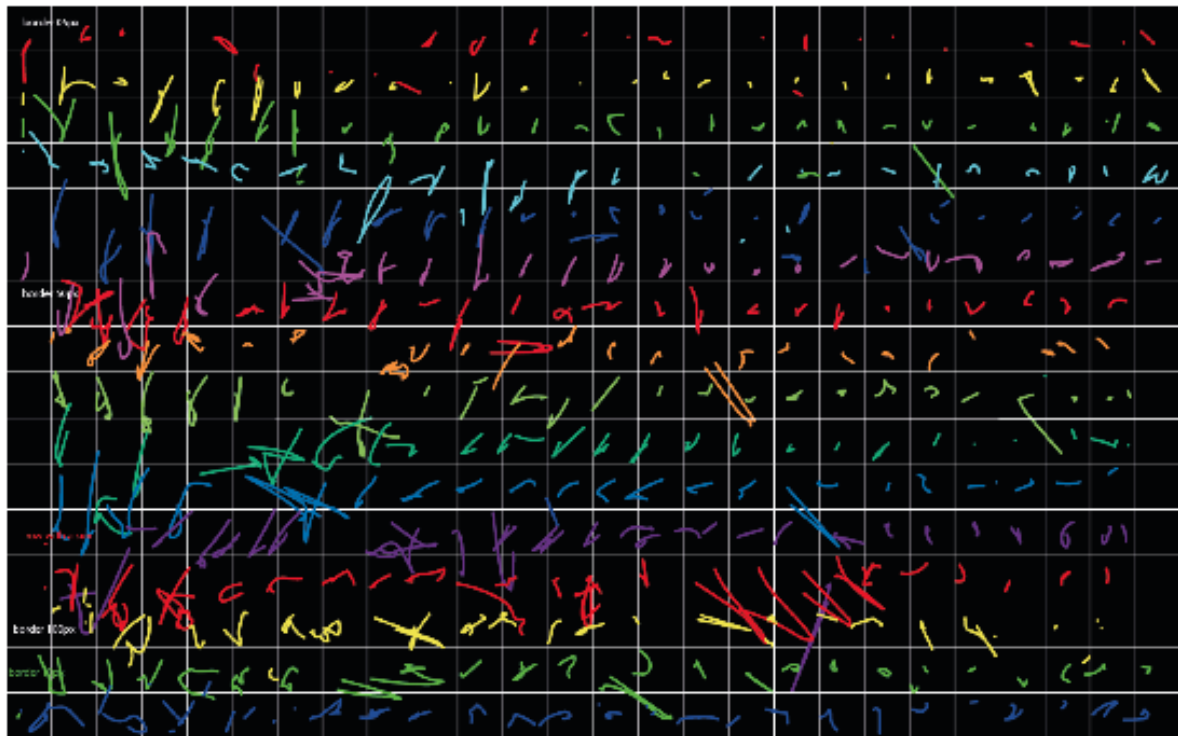


Figure 22. Calibration results.

## Application development

The application development environment was defined in previous subchapters. Unity is a cross platform game development engine. The application will be an 2D game, controlled by the touches of the projection on the table. The programming language which is used in Unity - C#, but for small and not sophisticated applications it makes sense to use visual coding add-on called "Bolt".

The core part of the exhibition is a 1:1 Minard map reprint. After considering several options for a possible composition, it was decided to place it on the right side of the table, orienting it as if the short side of the table was the direction of North-South (figure 24).

## Interface, chapters, design workflow

The storytelling of the prototype will follow the structure of the 1812.tass.ru "When Napoleon Ventured East" project as mentioned before. It is a very well structured and clear told story that the author is going to tell using the proposed method. The story consists of 12 chapters plus Intro and Epilogue. The chapters are dividing the period of the story into several sub-periods. Each period contains a list of the dates with the related content. A more clear structure can be seen in the source table which is shown in the figure 23 and in appendix III.

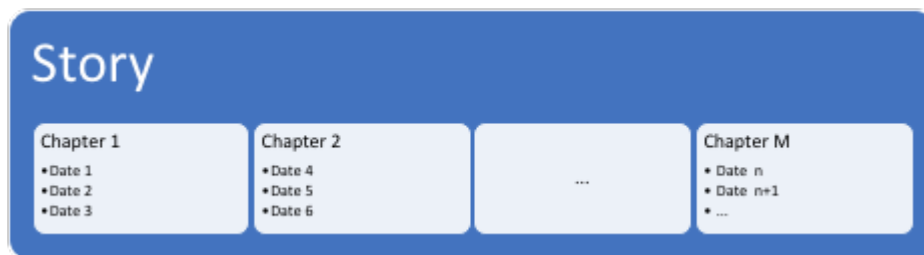


Figure 23. Chapter wise structure of the story.

This structure leads automatically to the interface of the prototype. The main component is a timeline. The ticks and the divisions of the timeline representing and indicating the individual chapters. The control buttons navigate the user to the previous and next date. There is a special field to show the current date. One of the first versions of the interface is shown in figure 24.

Each chapter of the story includes several dates. They are connected by a common background, but each date has its own design. Each date is a picture which is designed in Adobe Illustrator, considering the physical size of the map and interface. The navigation between the pictures is realised by the back and forward buttons and short links to the chapters. The interface elements were made from paper and cut with cutter plotter. After that it was glued to the table. The final interface can be seen in the figure 25.



Figure 24. The early version on the interface.

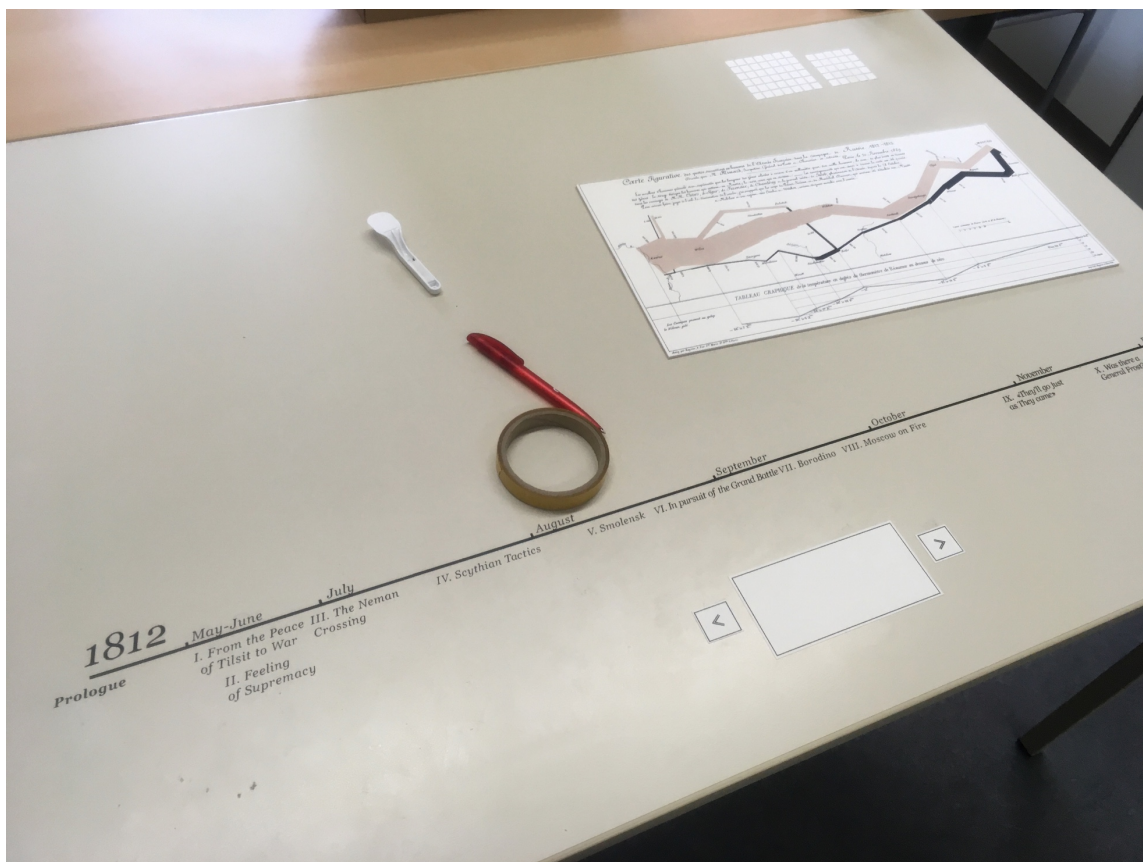


Figure 25. The interface at the final stage of installation.



## Types of content and it's representation

All data of the story as a pdf file and the application could be found in electronic attachment to the thesis. In the following, the main types of content and the ways of its representation will be described.

### Background images

Each chapter has its own background. Figure 26 shows the introduction screen, a painting “Napoleon near Borodino” by Vereshchagin. The background image is overlaid with different design elements and is darkened on the position where the Minard map will be shown in the next scenes in order to smooth the brightness.



Figure 26. The introduction screen.

### Dates

The dates are displayed on a special paper rectangle placed in the centre of the interface (figure 27). This has been done because the user always need to see the date. This is an effective and elegant solution of story navigation task.

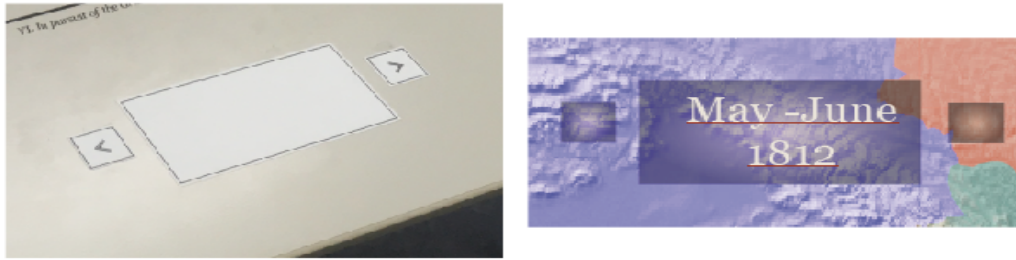


Figure 27. The paper rectangle for dates projection on the left; Screenshot of projected date from of the application on the right.

### Text

The contrast design solution was found to show text in special boxes using the same style in the all chapters and dates (example is shown in the figure 28).

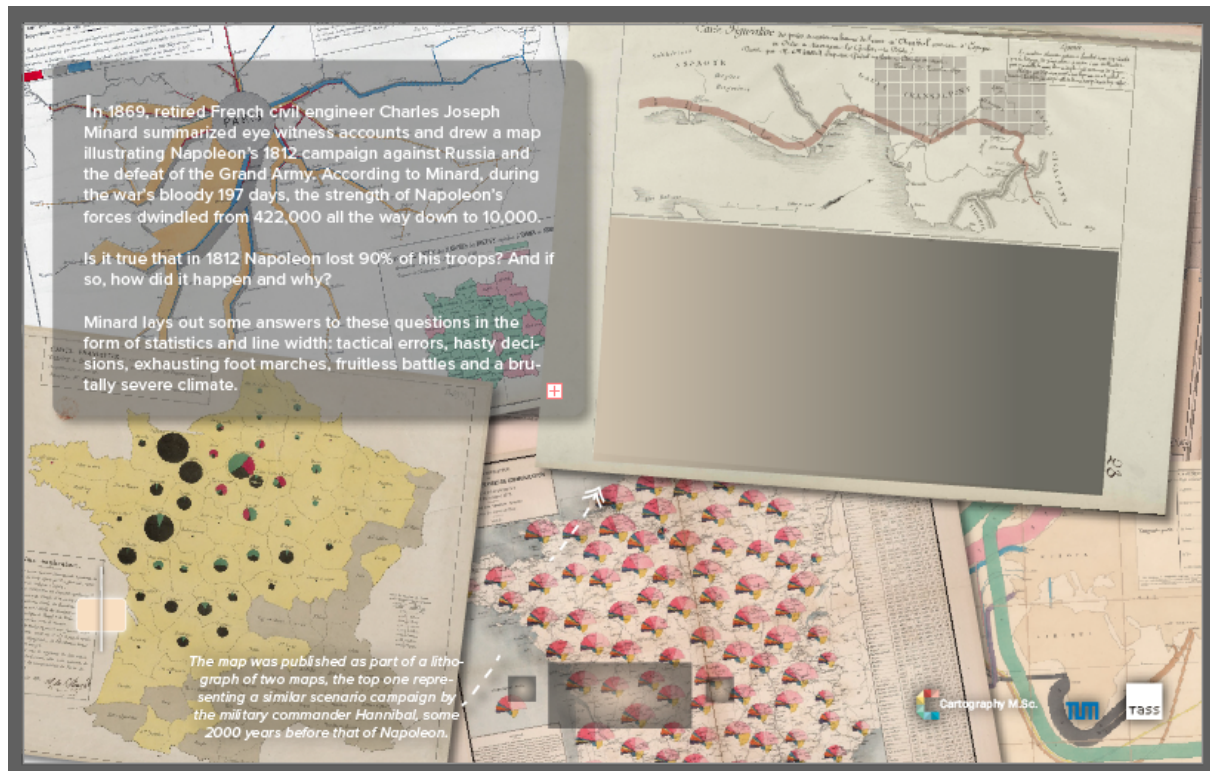


Figure 28. The Introduction chapter screen.

### Map overlay

One of the main goals is to incorporate the map as a storytelling instrument. In order to highlight the essential information of the map, the map is overlaid with an extra layer to place special emphasis on the route and the specific dates and locations. The graph is accumulated from the beginning of the campaign to the current date. In the figure 29 (left)

the highlighting is shown and the extra layers projected on the map and the table is shown on the right.

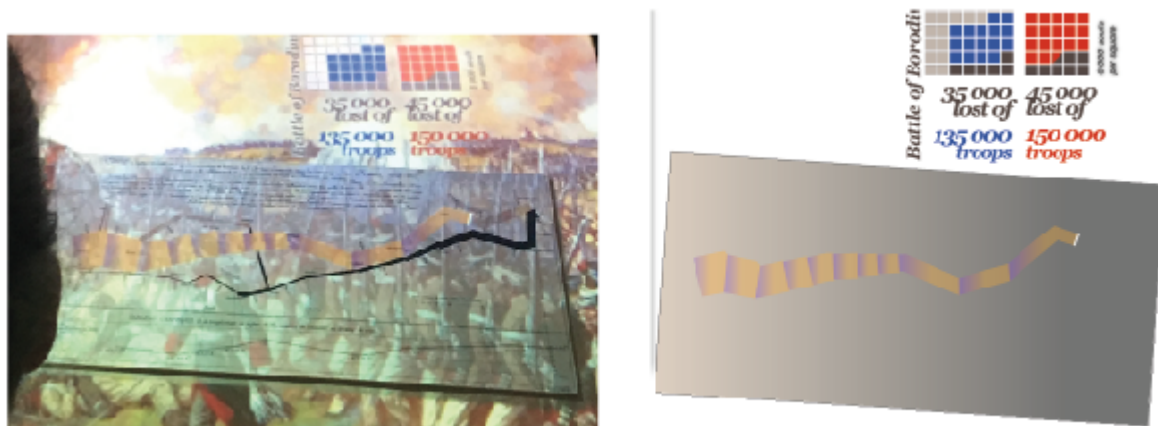


Figure 29. The extract from chapter IX and it's overlays.

### Timeline indicator

The current date displayed is shown with a vertical line on the timeline. The chapter is highlighted by a bright rectangle (figure 30).

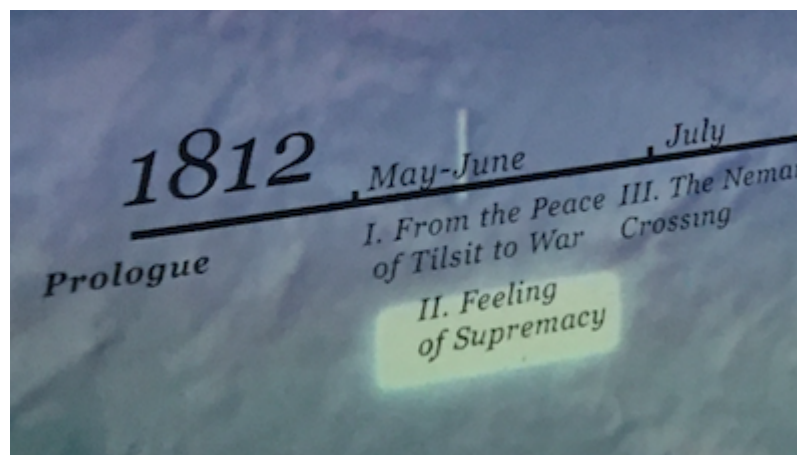


Figure 30. Timeline indicator.

### Overview maps

On the data preparation stage, the Minard map was georeferenced and aligned to the overview maps. With the help of the overview maps, the story background could be defined. Alternatively, some thematic maps could be shown - for example armies' disposition and amount in the begging of the campaign (figure 31 ). In this case, the Minard map becomes part of the overview map.



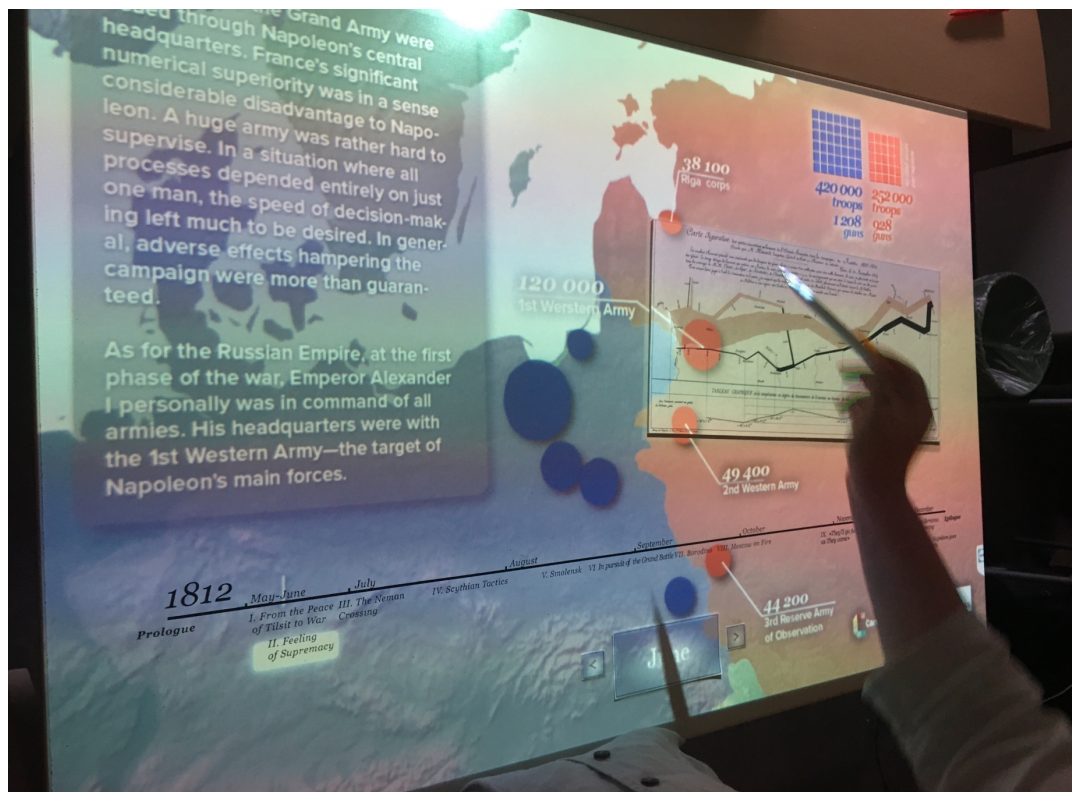


Figure 31. Armies disposition on the overview map.

Map in the text

If a more detailed map connected to the story is needed it could be included in the text. An example is realized in the chapter informing about the Moscow fire (figure 32).

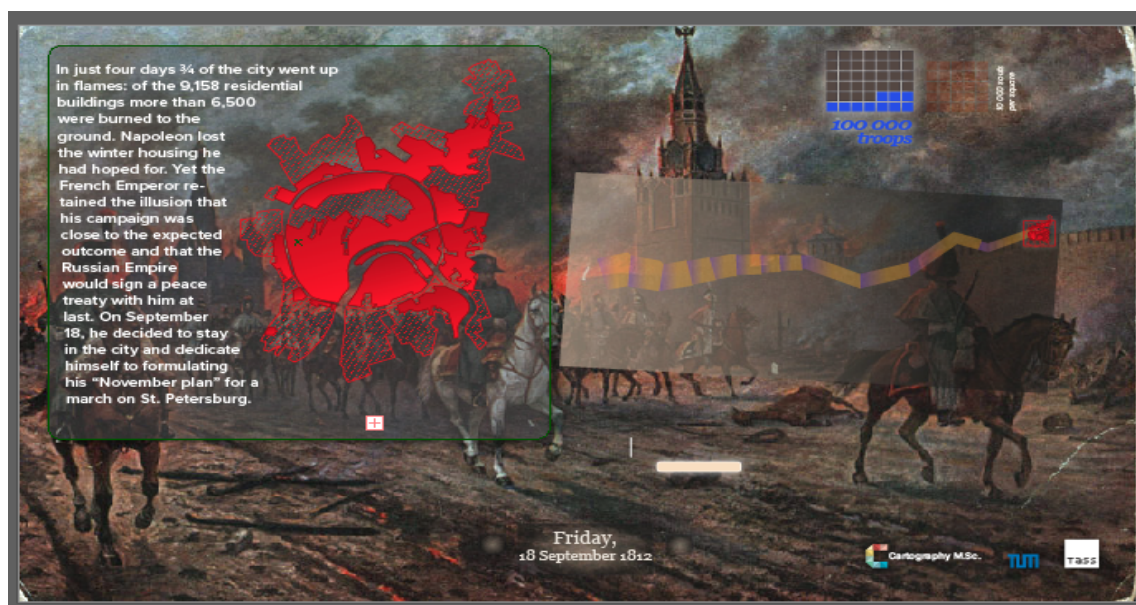


Figure 32. The Moscow chapter screenshot from the application, map included in the text.

### Troops indicator

For each date the information about of amount of the French troops was collected. In the physical interface the amount is shown by the square indicator infographics composed from the squares 10 000 souls each. The interactive projection fills with blue colour the part of the squares corresponding to the amount of the souls for the current date. When the amount of the Russian is known it is shown on the similar indicator on the right. The amount of the army is shown by the label down to the indicator as well. The example of indication is shown on the figure 33.

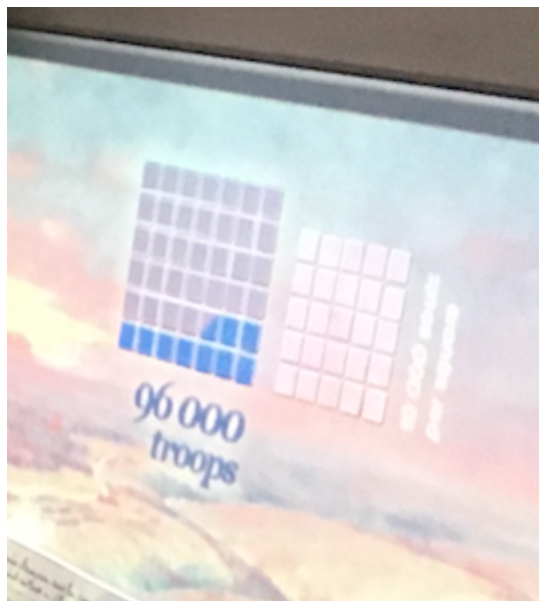


Figure 33. Troops indicator.

### Battles indicator

If dates contain battles, the troops indicator infographic switches to the battle mode. The amount of the soul's changes, information about of the losses is shown in figure 34. Red colour as everywhere in the exhibition is related to the Russian Army, Blue to the French army.

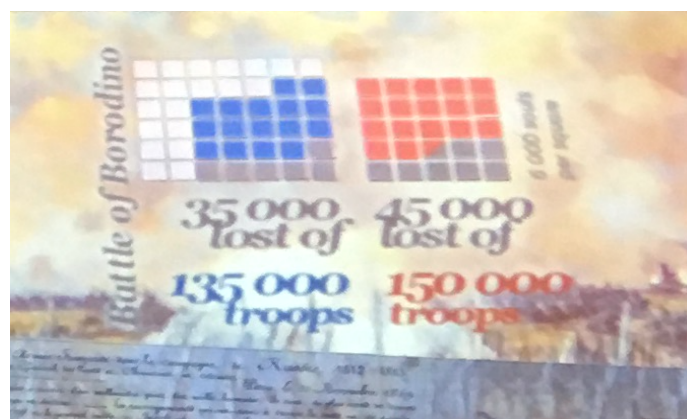


Figure 34 Battle indicator



### Soundtrack

An important element of immersion in a story is sound. For both versions of the exhibition, the Prokofiev's "War and Peace Symphonic suite" was integrated and used as soundtrack. Figure 35 shows the mounted AR exhibition in the final design. In the real setup the devices should be mounted into the wall to increase the depth of the immersion further.

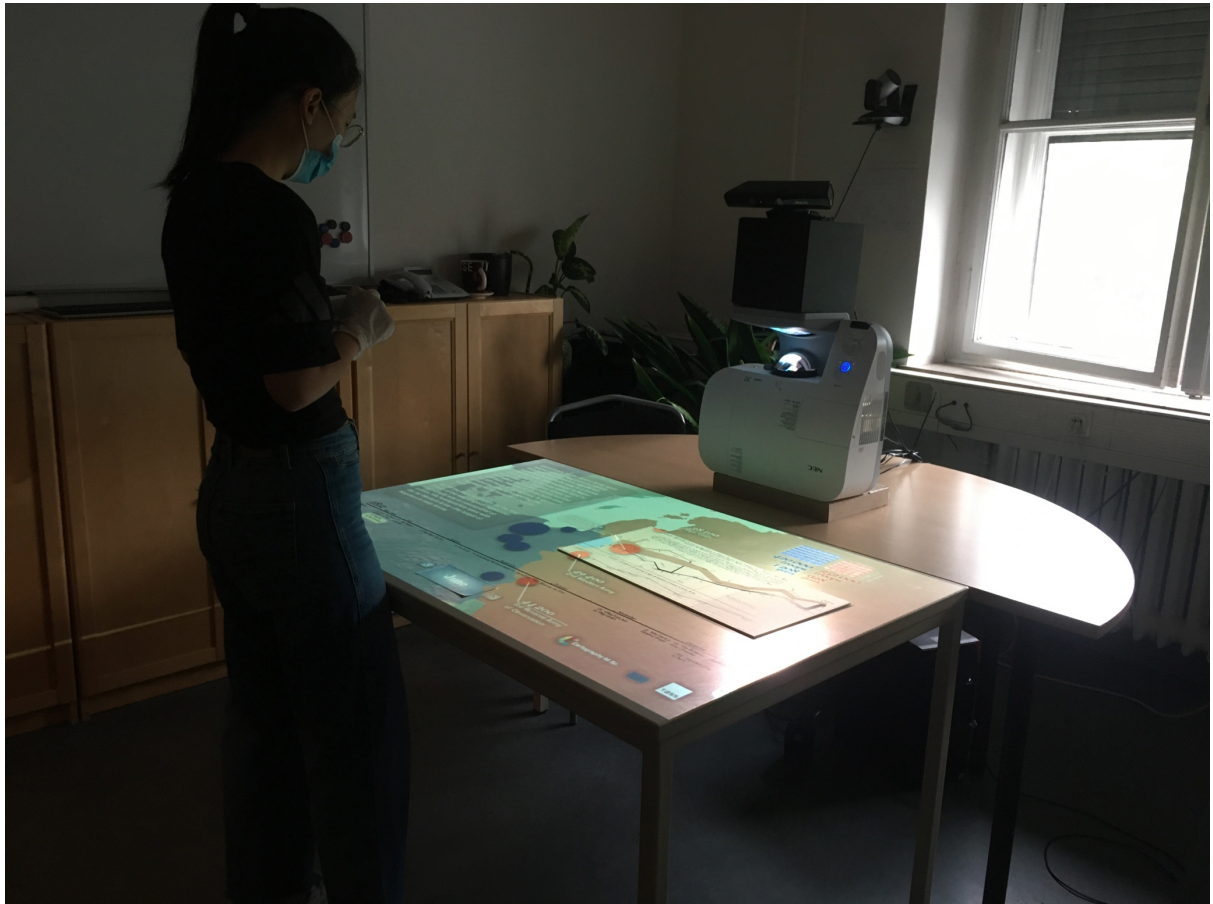


Figure 35. Mounted AR Exhibition prototype.

#### 4.2.2 Classical exhibition development

In order to reach research objective IV, a prototype telling the same story with only analogue instruments was developed. To emphasize the core exhibition element – the reprint of the Minard map – the map was placed identically to the AR exhibition (figure 36) and accompanied with text, images, infographics and sound.



Figure 36. Mounted Classical Exhibition prototype.

In the classical version, the same chapter wise structure as in the AR version was used. Additionally, the same digital content was integrated in the analogue version.

- Each screen corresponding to the date was redesigned to the page of the brochure with a chapter shortcut (1).
- An overview map was glued to the table in two colours (2).
- The Minard map overlay became a plastic foil overlay showing the positions of army on different days (3).
- The initial armies' disposition and amount of the troops are shown with popups (figure 37).
- A timeline was replaced close to the list of the contents (5).



Figure 37. Pop-up armies' indicator.

### 4.3 Evaluation

In order to compare both exhibitions and to find the impact of the AR exhibition on the user experience, a user study needs to be conducted. The goal is to compare both exhibition prototypes, AR and classical.

#### 4.3.1 Questionnaire and participants

Two paper-based questionnaires for both exhibitions with a similar structure have been developed. The questionnaires differ only in the user experience evaluation part.

The first block is a statistical block asking about geography, gender and age of the participants and measuring the familiarity with a map. The participants were asked to fill the block before they got time to explore the exhibition.

The second block consists of quantitative and qualitative questions about the Napoleons Russian campaign. Participants were asked to answer the questions of the second block after the self-exploration of the exhibition. They were also asked to talk and think aloud while answering the questions with the help of the exhibition.

The last block is a user experience feedback. Participants were asked to comment about their impressions of the whole prototype and different parts of the interface.

The questionnaires could be found in the appendixes I and II.

#### 4.3.2 Experiment setup

Both exhibitions prototypes were installed in one room (figure 38 ). Participants were randomly divided into two groups. One group was working with the AR exhibition (figure 39 ), the other with the classical one (figure 40 ). All the necessary COVID measures were followed and only one person was exploring the exhibition at one time. The whole user test took about 45-60 min per participant. The time was the same for both groups.



Figure 38. Classical exhibition prototype on the left; AR exhibition prototype on the right.

After completing the statistical block, participants were asked to imagine that they are in the Museum, and they want to explore the exhibition themselves. However, they were allowed to ask question like to a person guiding through an exhibition. After the self-exploration, participants received the second part of the questionnaire, which they were filling using the exhibition. The time needed for the exploration and to answer each question was recorded. After that users were invited to fill the last part of the questionnaire.





Figure 39. Participant exploring AR exhibition.



Figure 40. Participant exploring Classical exhibition.

The results of the experiment will be discussed it the next chapter.

## 5 Results and discussion

The data collected via questionnaires were digitised and processed in excel. The results analysis will follow the same structure as the questionnaire: (1) statistical block, then (2) tasks -to determine the quantity and quality of knowledge transfer and (3) user experience. Finally, (4) comments given in the open questions will be analysed and discusses. The questionnaires could be found in appendixes I and II.

### 5.1 Statistical block analysis

The total number of participants was 25. They were randomly divided into two groups. 13 participants explored the AR exhibition and 12 the classical exhibition. As shown in table 4 below, the two groups had almost the same size, male/female distribution, as well as age. The latter somewhat restricts the selection and should be taken into account during the analysis.

	AR	Classical
Number	13	12
Sex (male/female)	6/7	6/6
Age group (average/min/max)	21-29/21-29/41-49	21-29/21-29/41-49
Average familiarity with a map (0-4)	1,6	1,3
Self-exploration time, min (average/min/max)	11,7/3/44	7,7/5/13

Table 4. Groups statistics.

On a scale where 0 means not familiar with the map, 4 familiars with the map, the AR group is little more familiar with a map, but most of them are in the same category. It is interesting that the time of self-exploration is longer in the AR group, which means that users of the classical exhibition more easily become familiar with the interface of the prototype, and vice versa the AR interface needs more time to explore, maybe because of its attractiveness or complexity.

However, the groups are homogeneous in terms of age, sex and number of participants which makes it possible to compare the results of test.

## 5.2 Tasks block analysis

The second block - tasks - was the same in both groups. Users were invited to answer some qualitative and quantitative questions (number A-K) about Napoleon's campaign using the exhibition prototypes. The time with the participants spend while answering each question was recorded. The speed and correctness of responses can serve as indicators of both the quality of the transmitted information and the effectiveness of the prototype or its individual elements.

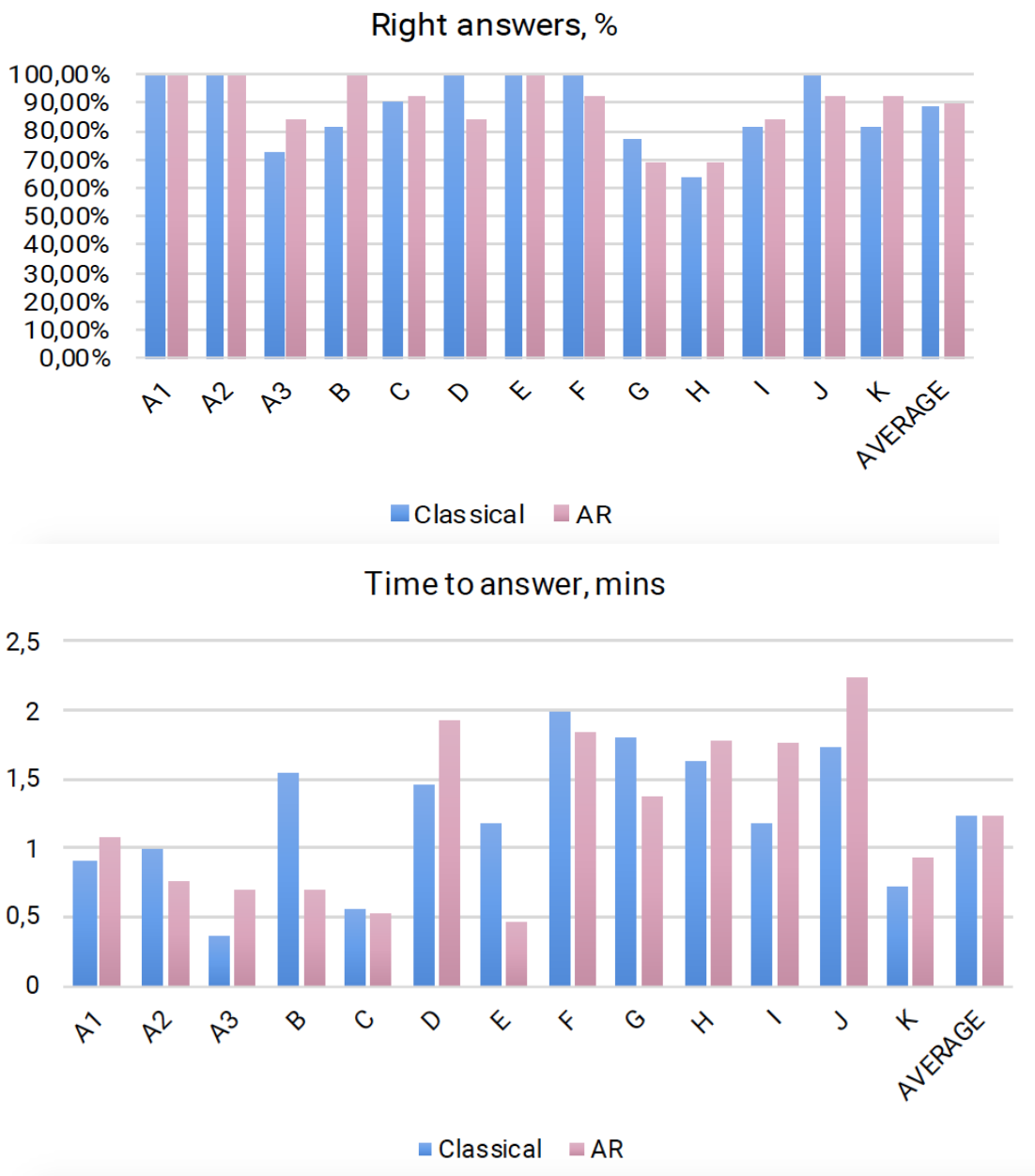


Figure 41. Percentage of right answers and time needed to answer the questionnaire.

As it is seen in figure 41, the average percentage of right answers and time needed to answer are nearly the same in both groups. This could indicate that the quality and quantity of the acquired knowledge is the same for both prototypes. The difference in indicators for individual issues indicates more or less successful design solutions for specific elements of the exhibition and requires a more in-depth analysis.

### 5.3 User experience analysis

The third block ( user experience evaluation) was different for each group, except for the first question. In that question, users were asked to rate the overall expression from the exhibition from three sides: (1) general, (2) the clarity of the interface, and (3) an opinion on the applicability of the exhibition in the real museums.

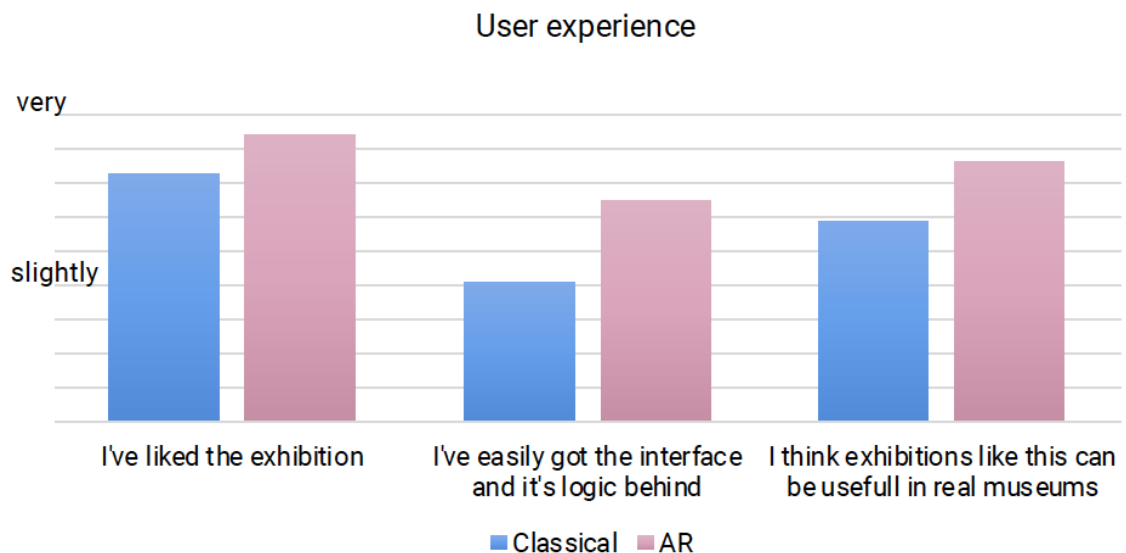


Figure 42. Overall user experience evaluation results.

The results of direct comparison allow it to be said that the hypothesis “the use of the method makes the exhibition more entertaining and enjoyable” is correct.

In all three aspects, the AR exhibition generated more positive feedback from participants (figure 42). This shows that both prototypes got a positive response. There are almost no negative reviews of individual elements of exhibitions in the questionnaires.

The rest of the questions were formulated in the same way and related to various elements of the exhibition prototypes. The strongest and weakest elements of each of the prototypes are shown in table 5.



	General comments		Interaction		Applicability	
Elements	Weak	Strong	Weak	Strong	Weak	Strong
AR	- Text - Sound - Interface	- Minard map overlay - Overview map - Timeline	- Interface - Map in the text	- Sound - Overview map	- Text - Background images	- Timeline - Map overlay
Classical	- Map in the text - Pop-ups	-Minard map overlay - Sound	- Text - Map integration	- Pop-ups - Booklet	- Booklet - Text	- Minard map overlay - Sound

Table 5. User experience evaluation.

The last two questions were open questions identical in both groups; users were asked to write down their impressions and suggestions. In the following, some comments given to both prototypes are analysed:

#### AR prototype

"It is creative and informative way to communicate a historical information to a wider public using various representation and audio media."

"That really fit to make historic events more interactive, so it could work for any war to illustrate troops movement"

"Any city history line would be great to be in an "interactive" exhibition like that"

The word "interactive" in positive context appeared in the user's comments, it once more time proves the hypothesis. Many respondents note that prototype is overloaded with text. This should be taken into account in the future studies. Some of the respondents note that quality of the picture and traction control could be better. This problem could be solved easily with better hardware.

#### Classical prototype

"I think the tasks helped me to understand the map and booklet better to be honest."

"Could be improved with better link and explanation between Minard's map, the full table map and the booklet"

“I liked the part to look for answers while connecting different elements of the exhibition, this was a really pleasant and excellent activity”

In the classical prototype feedback regularly noted that the task is a good instrument for the exploration. This idea as well as the idea of integrating a gamification process should be considered in the future research. The AR prototype respondents are noting that the exhibition is overloaded with text. This indicates, that AR exhibitions may do not need the same amount of texts and maybe sound (where somebody is telling the story with his/her voice) could be an option.

The comparative user study analysis shows that both exhibition prototypes received positive user feedback. The integrated storytelling elements provided all the instruments to solve the given tasks. However, the users found the AR prototype more entertaining and engaging. A more detailed look into the participants' feedback shows that some elements could be improved or replaced. This will be discussed in more detail in the last chapter.

## 6 Conclusions and outlook

The main objective of this study was to propose and evaluate a method of Map-based storytelling in Mixed Reality in order to enhance user experience.

To reach this research objective, an overview of current MR technologies for Cultural Heritage was made and the applicable hardware and software technology stack was selected. The different ways and possibilities of user interactions in an AR space were defined. Types of connected media (maps, map layers and information) that could be integrated in the exhibition were found. Two user groups explored two different prototypes developed for an exhibition and their user experience was finally compared.

The hypothesis that the proposed Map-based storytelling in Mixed Reality method could enhance user experience is proven. The AR prototype was ranked as more entertaining and is can be seen as a flexible storytelling solution including maps in a Spatial Augmented Reality environment.

Within the literature review, it was found out that for CH applications, a wide range of MR applications can be used. For the proposed integration of maps in exhibition with the MR method, Spatial AR was chosen as most suitable and entertaining option. This solution can overcome the traditional exhibitions limitations as space, time and non-interactivity.

The projection of interactive layers can be realized with the creation of Spatial AR in the intersection of the field of view of a depth camera and projector on the table surface with a paper map on it.

In the proposed method, users can interact with a touchable flexible interface in Spatial AR. Text, audio, video, overview maps, paper maps with interactive overlays, as well as animations, and other content could be added to a paper map in an exhibition.

The method of Map-based storytelling in Mixed Reality, as it shows the comparative user experience evaluation, makes storytelling using paper maps more entertaining and is enhancing the potential museums visitors experience.

Interactive map overlays, overview maps, a timeline and infographics have been identified as the most effective elements in Map-based storytelling in a Spatial AR environment and could be highly recommended for the priority usage in similar exhibitions.

The two developed prototypes however included too much text. In real museums, visitors will not spend this amount of time near one object. The benefit of the usage of animations and sound effects should be investigated in future studies.

The infographic interactively displaying the troops indicator shows its effectiveness, but should be made more clear for interpretation, for example by including a gamification component to the exploration process. The author of this thesis believes that if these identified shortcomings are corrected in the AR prototype, the sample prototype can be recommended fully for use in museums.

In future studies, maps of different topics, scales and geography should be used as a core of storytelling. The user group participating in the experiment was limited in terms of age and mostly came from the cartography field. It is recommended to expand the user test and include more users with different background and age in future. The comparison between the AR and the classical approach could be supplemented with on screen solutions. All three solutions could be compared and evaluated to derive more specific answers on the user experience enhancement. It is not clear yet, which specific role the “wow” factor of the AR exhibition plays in the user experience because of the use of a new entertaining technology.

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## APPENDIX I. When Napoleon ventured East AR exhibition. User test questionnaire



When Napoleon ventured East AR exhibition. User test questionnaire.

I. General info

- A. Name: \_\_\_\_\_
- B. Gender:
- ☐ Female
  - ☐ Male
  - ☐ prefer do not comment
- C. Age:
- ☐ 17 or younger
  - ☐ 18-20
  - ☐ 21-29
  - ☐ 30-39
  - ☐ 40-49
  - ☐ 50-59
  - ☐ 60 or older
- D. Country of origin : \_\_\_\_\_
- E. Are you familiar with the map of Napoleon's Russian campaign by Charles Minard?
- ☐ never heard about it
  - ☐ never seen it
  - ☐ quite familiar – have seen it on the lectures/in the media
  - ☐ very familiar – I've explored it a lot/ was using in the projects
  - ☐ I'm fan - I have poster with it on my wall

II. Please give answers, which you can find in the exhibition materials, to following questions about Napoleon's campaign to Russia

- A. What was the amount of troops of French army at:
  - 1. June 1812 \_\_\_\_\_
  - 2. 16 November 1812 \_\_\_\_\_
  - 3. 14 December 1812 \_\_\_\_\_
- B. Biggest French army division at June 1812 amount and name  
\_\_\_\_\_
- C. Biggest Russian army division at June 1812 amount and name  
\_\_\_\_\_
- D. What was the temperature on 1 of December 1812  
\_\_\_\_\_
- E. Who is Charles Minard?  
\_\_\_\_\_
- F. Where was Napoleon's army located, when the number of troops was 55 000?  
\_\_\_\_\_
- G. When and where was the biggest battle of the campaign?  
\_\_\_\_\_
- H. When Napoleon's army was indicated on the map with smallest amount?  
\_\_\_\_\_
- I. In which month did Napoleon leave for Paris?  
\_\_\_\_\_
- J. Who was Fyodor Glinka?  
\_\_\_\_\_
- K. When Napoleon arrived at Moscow?  
\_\_\_\_\_

### III. User experience feedback

*Please fill this block after you have explored the exhibition and after you have answered the questions from block II*

#### A.What is your general impresion?

	very	slightly	neither	slightly	very	
I <b>didn't</b> like the exhibition						I've <b>liked</b> the exhibition
It was <b>hard</b> to understand how the interface works and it's logic behind						I've <b>easily</b> got the interface and it's logic behind
I think exhibitions like this <b>can't</b> be usefull in real museums						I think exhibitions like this <b>can be</b> usefull in real museums

#### B.Please score the different elements of the exhibition

##### B1. Interface elements: buttons, links to the chapters

	very	slightly	neither	slightly	very	
I <b>didn't</b> like the interface						I've <b>liked</b> the interface
It was <b>hard</b> to understand how to work with this element						It was <b>easy</b> to understand how to work with this element
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

##### B2. Infographics: diagram wich indicate the ammount of troops

	very	slightly	neither	slightly	very	
I <b>didn't</b> like this element						I've <b>liked</b> this element
It was <b>hard</b> to understand how with this element works						It was <b>easy</b> to understand how this element works
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

**B3. Full screen overview map with diagrams**

	very	slightly	neither	slightly	very	
I <b>didn't</b> like this element						I've <b>liked</b> this element
It was <b>hard</b> to understand that it shows						It was <b>easy</b> to understand that it shows
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

**B4. Full screen images used as the chapters' background**

	very	slightly	neither	slightly	very	
I <b>didn't</b> like this element						I've <b>liked</b> this element
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

**B5. Original Minard map overlay showing current army position**

	very	slightly	neither	slightly	very	
I <b>didn't</b> like this element						I've <b>liked</b> this element
It was <b>hard</b> to understand that it shows						It was <b>easy</b> to understand that it shows
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

**B6. Integration of original Minard map with full screen overview map**

	very	slightly	neither	slightly	very	
I <b>didn't</b> like this element						I've <b>liked</b> this element
It was <b>hard</b> to understand that it shows						It was <b>easy</b> to understand that it shows
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

**B7. Story text**

	very	slightly	neither	slightly	very	
I <b>didn't</b> like this element						I've <b>liked</b> this element
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

**B8. Date indicator and timeline**

	very	slightly	neither	slightly	very	
I <b>didn't</b> like this element						I've <b>liked</b> this element
It was <b>hard</b> to understand how with this element works						It was <b>easy</b> to understand how this element works
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

**B9. Maps in the text block**

	very	slightly	neither	slightly	very	
I <b>didn't</b> like this element						I've <b>liked</b> this element
It was <b>hard</b> to understand that it shows						It was <b>easy</b> to understand that it shows
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

**B10. Sound accompaniment**

	very	slightly	neither	slightly	very	
I <b>didn't</b> like this element						I've <b>liked</b> this element
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

IV.

A. Do you have any comments, ideas or advices?

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B. If you think exhibitions like that can be useful, what comes to your mind? Which kind of stories could be told in this format

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## APPENDIX II. When Napoleon ventured East Classical exhibition. User test questionnaire

### I. General info

#### A. Gender:

- ☐ Female
- ☐ Male
- ☐ prefer do not comment

#### B. Age:

- ☐ 17 or younger
- ☐ 18-20
- ☐ 21-29
- ☐ 30-39
- ☐ 40-49
- ☐ 50-59
- ☐ 60 or older

#### C. Country of origin : \_\_\_\_\_

#### D. Are you familiar with the map of Napoleon's Russian campaign by Charles Minard?

- ☐ never heard about it
- ☐ never seen it
- ☐ quite familiar – have seen it on the lectures/in the media
- ☐ very familiar – I've explored it a lot/ was using in the projects
- ☐ I'm fan - I have poster with it on my wall

II. Please give answers, which you can find in the exhibition materials, to following questions about Napoleon's campaign to Russia

- A. What was the amount of troops of French army at:
1. June 1812 \_\_\_\_\_
  2. 16 November 1812 \_\_\_\_\_
  3. 14 December 1812 \_\_\_\_\_
- B. Biggest French army division at June 1812 amount and name  
\_\_\_\_\_
- C. Biggest Russian army division at June 1812 amount and name  
\_\_\_\_\_
- D. What was the temperature on 1 of December 1812  
\_\_\_\_\_
- E. Who is Charles Minard?  
\_\_\_\_\_
- F. Where was Napoleon's army located, when the number of troops was 55 000?  
\_\_\_\_\_
- G. When and where was the biggest battle of the campaign?  
\_\_\_\_\_
- H. When Napoleon's army was indicated on the map with smallest amount?  
\_\_\_\_\_
- I. In which month did Napoleon leave for Paris?  
\_\_\_\_\_
- J. Who was Fyodor Glinka?  
\_\_\_\_\_
- K. When Napoleon arrived at Moscow?  
\_\_\_\_\_



### III. User experience feedback

*Please fill this block after you have explored the exhibition and after you have answered the questions from block II*

#### A.What is your general impresion?

	very	slightly	neither	slightly	very	
I <b>didn't like</b> the exhibition						I've <b>liked</b> the exhibition
It was <b>hard</b> to understand how the interface works and it's logic behind						I've <b>easily</b> got the interface and it's logic behind
I think exhibitions like this <b>can't</b> be usefull in real museums						I think exhibitions like this <b>can be</b> usefull in real museums

#### B.Please score the different elements of the exhibition

##### B1. Booklet: amount of army infographics

	very	slightly	neither	slightly	very	
I <b>didn't like</b> the interface						I've <b>liked</b> the interface
It was <b>hard</b> to understand how to work with this element						It was <b>easy</b> to understand how to work with this element
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

##### B2. Pop-up armies indicator

	very	slightly	neither	slightly	very	
I <b>didn't like</b> this element						I've <b>liked</b> this element
It was <b>hard</b> to understand how to work with this element						It was <b>easy</b> to understand how to work with this element
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

##### B3. Full-table map

	very	slightly	neither	slightly	very	
I <b>didn't like</b> this element						I've <b>liked</b> this element
It was <b>hard</b> to understand that it shows						It was <b>easy</b> to understand that it shows
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

#### B4. Original Minard map reprint

	very	slightly	neither	slightly	very	
I <b>didn't like</b> this element						I've <b>liked</b> this element
It was <b>hard</b> to understand that it shows						It was <b>easy</b> to understand that it shows
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

#### B5. Original Minard map overlay showing current army position

	very	slightly	neither	slightly	very	
I <b>didn't like</b> this element						I've <b>liked</b> this element
It was <b>hard</b> to understand that it shows						It was <b>easy</b> to understand that it shows
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

**B6. Integration of original Minard map with full table map**

very slightly neither slightly very

I <b>didn't</b> like this element						I've <b>liked</b> this element
It was <b>hard</b> to understand that it shows						It was <b>easy</b> to understand that it shows
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

**B10. Sound accompaniment**

	very	slightly	neither	slightly	very	
I <b>didn't</b> like this element						I've <b>liked</b> this element
I think this element <b>can't</b> be usefull in real museums						I think this element <b>can</b> be usefull in real museums

IV.

A. Do you have any comments, ideas or advices?

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There is no text or other markings on the paper.

B. If you think exhibitions like that can be useful, what comes to your mind? Which kind of stories could be told in this format

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

## APPENDIX III. Source data table

Task, SCHE	Task ID	Date	Task Event	Task Event	Task Event	Mission/Event	Investment/Event	City	Troop/Asset	Troop/Asset	Troop/Asset	Troop/Asset	Troop/Asset	Qty	Unit	Date, Time
PROCESSES: Monitoring																
PROCESSES: Monitoring	9999	Mon 4 Jul 1812														
PROCESSES: Monitoring	1	Tuesday 23 Jun 1812														
PROCESSES: Monitoring	1	Wednesday 24 Jun 1812														
PROCESSES: Monitoring	2															
PROCESSES: Monitoring	3	Tuesday 23 Jun 1812														
PROCESSES: Monitoring	4	Friday 26 Jun 1812														
PROCESSES: Monitoring	5	Saturday 27 Jun 1812														
PROCESSES: Monitoring	6	Sunday 28 Jun 1812														
PROCESSES: Monitoring	7	Monday 29 Jun 1812														
PROCESSES: Monitoring	8	Tuesday 30 Jun 1812														
PROCESSES: Monitoring	9	Wednesday 1 July 1812														
PROCESSES: Monitoring	10	Thursday 2 July 1812														
PROCESSES: Monitoring	11	Friday 3 July 1812														
PROCESSES: Monitoring	12	Saturday 4 July 1812														
PROCESSES: Monitoring	13	Sunday 5 July 1812														
PROCESSES: Monitoring	14	Monday 6 July 1812														
PROCESSES: Monitoring	15	Tuesday 7 July 1812														
PROCESSES: Monitoring	16	Wednesday 8 July 1812														
PROCESSES: Monitoring	17	Thursday 9 July 1812														
PROCESSES: Monitoring	18	Friday 10 July 1812														
PROCESSES: Monitoring	19	Saturday 11 July 1812														
PROCESSES: Monitoring	20	Sunday 12 July 1812														
PROCESSES: Monitoring	21	Monday 13 July 1812														
PROCESSES: Monitoring	22	Tuesday 14 July 1812														
PROCESSES: Monitoring	23	Wednesday 15 July 1812														
PROCESSES: Monitoring	24	Thursday 16 July 1812														
PROCESSES: Monitoring	25	Friday 17 July 1812														
PROCESSES: Monitoring	26	Saturday 18 July 1812														
PROCESSES: Monitoring	27	Sunday 19 July 1812														
PROCESSES: Monitoring	28	Monday 20 July 1812														
PROCESSES: Monitoring	29	Tuesday 21 July 1812														
PROCESSES: Monitoring	30	Wednesday 22 July 1812														
PROCESSES: Monitoring	31	Thursday 23 July 1812														
PROCESSES: Monitoring	32	Friday 24 July 1812														
PROCESSES: Monitoring	33	Saturday 25 July 1812														
PROCESSES: Monitoring	34	Sunday 26 July 1812														
PROCESSES: Monitoring	35	Monday 27 July 1812														
PROCESSES: Monitoring	36	Tuesday 28 July 1812														
PROCESSES: Monitoring	37	Wednesday 29 July 1812														
PROCESSES: Monitoring	38	Thursday 30 July 1812														
PROCESSES: Monitoring	39	Friday 31 July 1812														









B. LUNCH FROM 12:00 TO 1:00 PM	168	Monday, 7 December 1812.		26.2	10.000	11.800	75	1
	169	Tuesday, 8 December 1812.				0	0	
	170	Wednesday, 9 December 1812.	208.1	8.000	8.000	8.000	26	0
	171	Thursday, 10 December 1812.				0	0	
D. LUNCH FROM 12:00 TO 1:00 PM	172	Friday, 11 December 1812.		8.000	8.000	10.800	27	0
	173	Saturday, 12 December 1812.				0	0	
	174	Sunday, 13 December 1812.				0	0	
	175	Monday, 14 December 1812.				0	0	
	1800						75	1

## APPENDIX IV. Participants comments

### AR exhibition

#### Nº16

##### A. Do you have any comments, ideas or advices?

I think it's a god idea to highlight the temperature and troop size with light. But I could not understand the Minard map easily, as it was the first time, I saw it and the letters were so small. I like the layout though. Also, the image is blurry. I gained some knowledge about the battle. But there are so many elements, as a first-time user, I sometime forget where to look for the information.

##### B. If you think exhibitions like that can be useful, what comes to your mind?

##### Which kind of stories could be told in this format

Historical events like this, But maybe not very complex ones? With some many dates. Users may get lost.

#### Nº18

##### A. Do you have any comments, ideas or advices?

It is creative and informative way to communicate a historical information to a wider public using various representation and audio media. The combination of text and visual content gives \*\*\*\* overview. Along with the overview the details of the historical event can be discovered \*\*\*\*. The music playing along the exhibition makes the whole experience authentic. Vertical disposition would be preferred (my poor neck:))

##### B.If you think exhibitions like that can be useful, what comes to your mind?

##### Which kind of stories could be told in this format

History of planet evolution? Animal movement. Regional development. Flooding. Etc. I see a wide range of different applications using the proposed method.

#### Nº19

##### A. Do you have any comments, ideas or advices?

No that was fun

##### B.If you think exhibitions like that can be useful, what comes to your mind?

##### Which kind of stories could be told in this format

That really fit to make historic events more interactive, so it could work for any war to illustrate troops movement? Or it could also be used to \*\*\* exploration trip (e.g. discovery of America etc.)

#### Nº20

##### A. Do you have any comments, ideas or advices?

1) Because the exhibition is text based more that visual based in the sense that visitor will not be able to understand anything it he/she will not read the text, it exclude some visitors with reading disabilities. Maybe some smaller and clear summaries in the start of every chapter, additionally with the text now would be helpful. 2) I liked the visuals although I think a bigger table would help to un-crowd

the visuals. 3) It took me some time to understand the original map. I think an explanatory slide in the start might be more welcome for every visitor.

**B.If you think exhibitions like that can be useful, what comes to your mind?**

**Which kind of stories could be told in this format**

Any city history line would be great to be in an "interactive" exhibition like that

## **№22**

**A.** To make it more like game- open card with text etc.

too much text

static location of armies (blue/red pop-up)

**B.** first WW(two fronts )

second WW (two fronts + Asia )

civil men in USA

French - Prussian war 19 cents

## **№24**

- A.** Temperature is hard to find. Add solder (солдатики) to the Minard Map. 1 solder=20.000 etc. Integrate the solder count block from top right as \*\*\* block on the Minard Map. Use other place (for \*\*\*\* main \*\*\*\* position) to explain forces during battles.

**B.** II World WAR

## **№1**

- A.** The diagram displaying troops could be made to be more easily understood/ Timeline sometimes didn't match.
- B.** Almost any historical event involving time. Ex. US westward expansion. Us railroad construction. cross country James Cook ship travel across the world

## **№3**

**A.** It is a very informative and well-done exhibition piece. The \*\*\*\* made we realize the dimensions of the campaign (I thought Napoleon went a longer way!) and the troop indicators made it easy to understand the amounts of soldiers lost. Indicators was a little did \*\*\*\* but worked well after realizing the \*\*\*\*. A piece that could stand in an interactive museum! Maybe Minard's map could be clickable too!?

**B.** Everything that has a time - and space \*\*\*\*\* ideas. Sailors like Columbus, Drake, Magellan, the search for the Poles, the northern passage ( HMS Terror), journeys Marco Polo, Ernest Shackleton, Amundsen VS Scott etc. The Alaskan Gold Rush, the movement of settlers to the Pacific coast the immigration stories of groups or individuals, maybe even the first landing on the Moon etc.!

## **№5**

**A.** (B1)For a prototype I found it impressive. b) in Principal yes, but some links e.g. Between troops on the upper right \*\*\*\* Number on \*\*\*\*\* \*\*\*\* are understood in a 2nd glance. General^ I found the prototype in general very explorative especially

since it is quite a complex topic. I also perceived it an intuitive with clicking on the button and supporting \*\*\*\* but exploratively and intuitively \*\*\* or \*\*\*\* themselves a bit ... So, in the beginning a small introduction video or explanation or a person or the basic function and links between \*\*\*\*, But very explorative, super useful for museums and quite impressive! Good job! =)

**B.** - all kind of great book story's e.g. Harry Potter, Star Wars, Lord of The Rings etc. e.g. exhibition of fantasy stories. -Fairytale would be awesome - Real Big happenings like you did French Revolution, but also cold war, DDR lite, Berlin war, Old Greeks, Old Egyptians Tutankhamunnumnumnm, \*\*\* Single stories about Big happenings in \*\*\* The development of penicillin. How drugs work (scenically) ->over time --> Basically you could tell every story which has \*\*\*\*and\*\*\* reference

## **№7**

### **A**

**B.** More or less every story in place and time

## **№9**

**A.** 1/ Colors on the Minard's map; path blue, not purple-yellow, please. 2. \*\*\*\* scale on troops \*\*\*\* (reading "x souls per square" doesn't help...). 3. I would like the timeline to be more precise, e.g. one \*\*\* tick per day, maybe with highlighted ticks for days where something happens. 4. Some indica\*\*\*\* of the number of pages each chapter has would be nice - \*\*\*\* without the chapters. 5. A possibility to look closer at each map 1 graphs (\*\*\*) would be nice. 6. Being able to jump to places by clicking on the map

**B.** - The "discovery" of America -expedition like Alexander \*\*\*\* for example. - Any war campaign, \*\*\*\* - Travels of painters or poets along with their art, e.g. \*\*\*\* Holy Travels

## **№ 11**

**A.** Very interesting idea and great \*\*\*\*. Some small details could be corrected from my point of view. Maybe it is not possible but would be better if the original Minard map was a bit bigger. On some slides I noticed that text on the left side from the diagram sharing the number of troops overlapped with squares. In general, would be better to have more time to explore this detailed exhibition

**B.** Historical events, every story that has timeline and geographical location or info

## **№ 13**

**A.** Индикация битвы отдельно от количества армии. Название главы перед текстом. Дата на белом фоне. Подсветка температуры

**B.** Ход войны/сражения, смена границ государств с течением времени. МИИГаик народов. Потоки беженцев

## **Classic exhibition**

### **Nº 21**

**A.** I liked the visual red/blue color coding for different armies.

maybe it could be useful to unify font sizes and their styles -> somehow map of Minard felt "disconnected" from the table map, booklet and content.

it would be nice to see stronger visual connection between map of Minard and booklet, e.g. indices on the map speeding up and showing in with part of the booklet I could find the info.

initially I thought indices on the booklet one month of 1912;).

I could somehow relate to the story because of my origin, somehow maybe it would be of a benefit for non-EU users to relate the numbers to the main cities populations? Also name of a Baltic sea would be of a help ;)

**B.** I liked the part to look for answers while connecting different elements of the exhibition, this was a really pleasant and excellent activity

### **Nº14**

**A.** I think the tasks helped me to understand the map and booklet better to be honest. Solely let myself just into explore the map and booklet I will lost and miss a lot of details. If I in the museum and just explore it by myself. I would assume to spend most of my time into the booklet, because it provides better details

**B.** if the exhibition is located in the museum, the reality is not everyone has chance to spend 30 minutes to explore it. In my opinion if we want to fully understand the whole storyline and get all details 30 mins is necessary. To make full use of the map is the most efficient way to speed up the process. But this exhibition didn't make very good use of map. Map looks like an attachment to the booklet

### **Nº12**

**A.** It is a very interesting implementation of already quite known historical fact. I liked mostly different means and ways of providing information. Separate content table is a very nice element as in museum it would give a visitor opportunity easily find info in booklet. Textual information makes map also more fun with some historical facts. At the beginning I thought that the Map of Minard was not attached to the table and tried to move it. Only after some seconds I've understood the concept which is really nice. Pop-up are always good idea. I think as people are usually curious what is hidden being there. Very nice and very well done.

**B.** historical stories, traveling stories, personal stories of interesting people, environmental aspect can be also shown, but I guess a human/history/culture related stories are the most exciting to tell in this diverse way

### **Nº 17**

**A.** The Minard map is in an unfamiliar language an overlap with language guide might help in better understanding of the map. It was hard to tell whenever the map is trying to represent the armies of both sides or just the Napoleon army

**B.** Many historical stories of wars, journeys, migration and moment of human civilization can be shown such exhibitions

## **№ 2**

**A.** 1) Duplicates, types, other errors to clean up 2) The tabs/bookmarks were confusing. 3) The red blue army locations on the map weren't very tied to the booklet info. 4) So much reading! Tiresome halfway through. 5) Very linear + length makes it feel like on exploration and more like a dense story. 6) Maybe state the purposes of the different piece upfront somehow. 7) Did not notice the dates at the bottom of the booklet at first. 8) The quotes are nice but distracting and break the flow for me; maybe different font/not capitalized would be less distracting. 9) I did not understand the use of the army markers and did not feel any need to use them while reading the booklet.

**B.** This format feels nice for journeys and explorations if the stages are not too dense with additional/unrelated information. Exploration, battles, colonization, migration, stuff like that with enough detail on a single scale.

## **№ 4**

**A.** - Could be improved with better link and explanation between Minard's map, the full table map and the booklet. - Minard's map was hard to interpret quickly. - I feel the table map is a great idea, but could maybe contain more information and interactivity but I do understand this was just a prototype :-)

**B.** -I agree it is good for showing things relating to war. - Stories with timelines

## **№ 6**

**A.** The music was too loud (at first). A more logic overview of the booklet could help. I.e. Clearer Chapter Separations. There could have been a little more information on the pop-ups. i.e. General/Marshal

**B.** The paper pop-ups could be \*\*\* out after short time. Only one person at a time can view it properly. Some French translations would help to make the items holistically more consistent. The map overlay should be fixed in an easier to understand way

## **№ 8**

**A.** It was hard to find officers. If these would be served tables showing the important historic events would be better. The pop-up paper could be replaced with figures

**B.** It would be very interesting to show the marching environment, Eng., landscape, \*\*\* ....

## **№ 10**

**A.** Maybe Minard's map an also be printed on transparent paper so its placement on the top of the table map looks mor intentional. Suggest moving the infographics lower on the page

**B.** I liked the part to look for answers while connecting different elements of the exhibition, this was a really pleasant and excellent activity

## **№ 15**

**A.** Include Translation of Minard's original map. Instead of using a "flip book" to explain the stages, maybe find a way of showing all the information at once. For

example: set the map against a wall and use the wall to portray the information  
booklet -> no pages have to be turned

**B.** It is a great way of showing how people move across different regions over a certain period of time. It can be used in the context of army movements, but also migration.

**№ 19**

**A.** No that was fun

**B.** That really fit to make historic events more interactive. So, it could work for any to illustrate troops movement. So, it could also be used to \*\* exploration trip (e.g. discovery of America etc.)