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An Empirical Evaluation of the Story Focus Concept – The Example of a Map Telling the Story of "The Legend of Meng Jiangnu"

ADEBAYO .Y. ISHOLA

Technical University of Munich

TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

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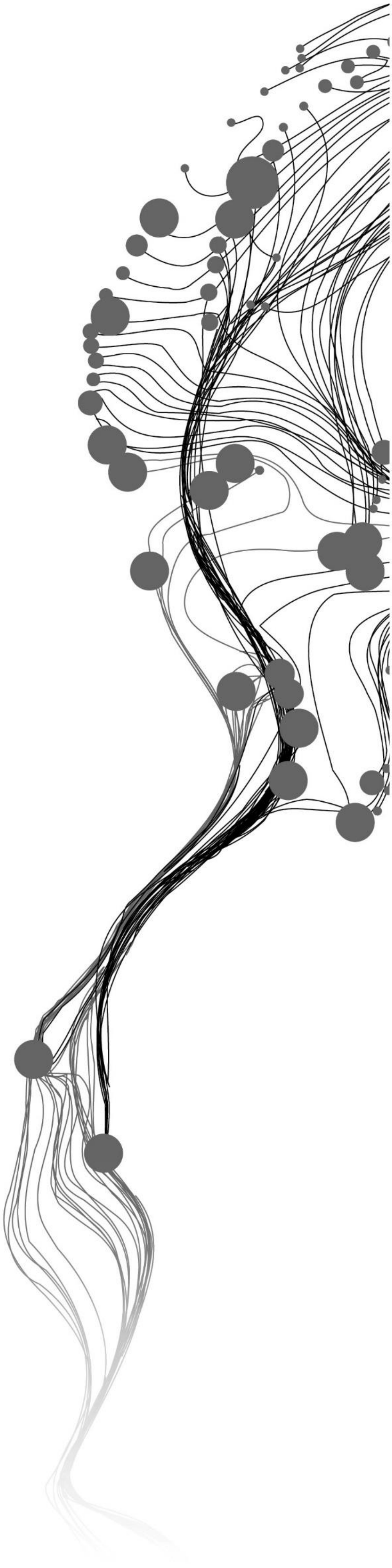

An Empirical Evaluation of the Story Focus Concept – The Example of a Map Telling the Story of “The Legend of Meng Jiangnu”

ADEBAYO YUSUF ISHOLA

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SUPERVISOR:

Dr F.-B. Mocnik

THESIS ASSESSMENT BOARD:

Prof. Dr M.-J. Kraak (Chair)

Dr F.-B. Mocnik (Advisor)

E.P. Bogucka (Reviewer, Technical University of Munich)

ABSTRACT

Maps tell stories using different techniques and media. Multimedia maps are one of the popular maps on the Internet used in telling stories today. However, in terms of effectiveness in arresting and retaining the attention of map readers, limitations exist with maps created alongside supplementary media such as texts, pictures or videos.

This research evaluates the story-focus concept, which proposes to incorporate the characteristics and aspects of a narrative text into a map as a way of effectively communicating and engaging map readers. A cartographic representation was implemented for an example story, the legend of Meng Jiangnu, using open-source web mapping frameworks and tools. Experiments were then conducted using methods of eye-tracking, questionnaire and interview to assess how effective the created map was in conveying the story and what aspects could be transferred from the text to a map.

By combining the results from the eye-tracking exercises, the questionnaire responses and the interviews, it was revealed that it is possible to guide and retain the attention of map readers to certain parts of a map using focus techniques. It also showed that it is also possible to transfer aspects of a text narrative like the atmosphere and spatial context. Results from this study can serve as guidelines in creating cartographic representations that engage a map reader's attention.

Keywords: *Narrative, storytelling, maps, cartography, story focus*

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1. INTRODUCTION

1.1. Research Context

In understanding our world, data is presented as information on devices like maps, paintings and narratives (van der Valk, 2019). Moreover, historically, with the mention of place, maps are involved. This is because maps are capable of revealing connections and trends (Kraak & Fabrikant, 2017) of a place. Both tangible and intangible phenomena of a place can also be displayed on a map. A map can provide answers to questions such as: Where is the Eiffel Tower? How many parks are there in Enschede? What is the average temperature in Nigeria today? In communicating delicate information visually and in storytelling, maps are an incredible means.

Storytelling has been used in many ways and several domains. Predominantly, cartographers use maps to tell stories. Data journalists, historians and data visualization engineers also use maps to communicate facts, fiction and issues.

Visualization researchers have mainly found maps as a powerful medium in communicating compelling stories (Lee et al., 2015) from data. Researchers have been exploring the possibilities of telling historical, cultural and fictional stories on maps while transferring the characteristics of the narratives. Their works have highlighted the need to extend mapping stories beyond the space-time properties of places to include other features such as the expression of emotions, context and atmosphere.

Segel and Heer (2010) investigated design space in narrative visualization, identified emerging patterns and proposed techniques for narrative visualization. Design space analysis was conducted by analyzing 58 visualization examples collected from online journalism sources. The outcome of analyzing the data stories was the design of unique genres defined by visual narrative tactics and narrative structure tactics. They, after that, proceeded in designing a taxonomy of design elements that facilitates the reader's interpretation through well-layered meanings, and interaction between these design elements which would serve as a guide in creating visualizations to convey stories engagingly.

The work of Caquard and Naud (2014) addressed fundamental concerns in mapping cinematographic narratives. They were able to develop a methodological framework and designed a cybercartography application to map movies narratives. A spatial topology was created based on three conditions: the place of the action, the relationship between the locations and the multiplicity of the locations as the stories unfold. Based on these three criteria, 46 Canadian films were mapped and analyzed, and four recurring narrative forms were observed. The movies were either unipolar (story unfolds in just one location), bipolar (story unfolds between only two locations – back and forth), multipolar node (story unfolds in multiple locations but emanates from a central node) or multipolar circular (story moves between more than two locations without returning to a central node) in form. They also held the opinion that narrative places should have its spatial unit, and the confidence level associated with a location should be represented.

Caquard and Cartwright (2014) explored a post-representational concept of mapping stories. Their research took two cartographic perspectives: maps representing the spatial features of stories and the narrative power of a map. Emphasis was made on the critical role of developing narratives that describe the process in mapping stories as well as the context as they unfold. The identified fundamental issues for mapmakers in narrative cartography such as sequence representation, visualizing stories unfold at multiple scales, emotions conveyance and the inclusion of fantasy locations in the mapping (written, oral and audio-visual) of stories to their referential places. They, however, neither implemented nor tested the concept.

In a study by Mocnik and Fairbairn (2018), a novel cartographic concept called "story focus" was proposed. Story focus entails incorporating the story told within the same map representation, unlike in digital and multimedia maps where additional media like texts are transported alongside the map. The new concept emphasizes some aspects of the text in modifying maps such as the temporal and non-spatial context, local-scale variability with time, increased expressivity through open-world assumption, and the atmosphere as the story unfolds. They demonstrated the possibility of employing cartographic creativity and writing processes to develop maps that tell stories more effectively. The researchers postulate that their approach will allow for effective communication and expose engaging narratives within maps to tell stories.

Yuan (2020) discussed Geographical Information Science and Technology (GIST) approaches to geographically enhance the communication and representation of historical landscapes by incorporating the processes and transformations. A review into the possibilities of traversing phenomenological and cartographic perspectives revealed the crucial role human experiences and the physical environment play in comprehending landscapes. The author explored how geographic attributes, emotions and events can be incorporated in GIST methods of spatial narratives, geo-narratives and deep mapping of landscapes. Spatial and geo-narratives emphasize personal stories of landscapes leaving out the landscape experience itself, while deep maps utilize multimedia elements and multiple layers of data to record both the physical and human experience of a landscape.

The research community has identified the need to transfer personal experiences and accounts to maps to enhance the quality of maps in storytelling. Clearly, much work has been put into developing methods and conceptual frameworks to achieve richer cartographic representations of narratives.

1.2. Motivation and Problem Statement

Advancements in mobility mean that people can now travel to places of their choice and at the time they desire. These locations vary from a few to hundreds and thousands of kilometres with lots of resources to be invested. Travellers often need to plan to maximize their limited resources by getting a good description of where they would be departing for and as realistic as possible in terms of experience and expectations. Students who desire to start their education in another city are usually eager to know what it is like living and studying there as well as how to navigate their way there. Tourists also tend to seek out exposés of famous historical sights and landmarks they would be exploring. These individuals have a shared need: "how do I get to the place?" and "what does the place feel like?"

In answering the question of "how do I get to the place?", maps have been a reference medium while "what does the place feel like?" has been conveyed via text-alike mediums – blog posts, individuals diaries and guidebooks. Maps are generally known to use symbols which in contrast to text medium uses words in understanding a place. Rather than have a map and read a lengthy blog post or several pages of a guide book, will it be possible to capture both the location and the linguistics of the text in a single communication device and give the reader a good perception of a place (Mocnik & Fairbairn, 2018)?

Very often, the terms "narrative" and "story" are used interchangeably. The relationship between these two terms is that narratives give form to a story as events unfold (Bach et al., 2018). Narratives help in informing readers about events and enable the comprehension of divergent facts (Tateosian et al., 2019). Furthermore, in visualizing narratives selecting an appropriate sequence technique (Hullman & Diakopoulos, 2011) to tell the story as it unfolds is crucial.

Figure 1-1. Teresa Carpenter's NY diaries of mapping Manhattan. (Maria Popova, 2013)

Figure 1-2. Marvel Comics map of Manhattan (EAST BOROUGHS - EAST (Upper Manhattan, Bronx, Queens, Brooklyn) (Bob, 2017)

Information visualizers, Illustrators and Cartographers have designed and integrated different strategies on devices (Meier et al., 2019) to tell stories. Figure 1-1 and Figure 1-2 are examples of story maps of an individual and Marvel's comic characters in Manhattan, USA, respectively. Both maps describe events at different locations by including the narratives in Latin characters but introduces difficulty in controlling the reader's focus as the text content increases. With the advancements in web technologies, multimedia maps have also been designed to tell stories (Berendsen et al., 2018) by integrating the stories as text media e. g. as popups. Despite the similarity in purpose and techniques, a single representation that incorporates text narratives in a map is yet to be implemented.

This research is guided by the hypothesis that maps can convey stories more effectively by directly incorporating the narratives of the stories in the cartographic representation as opposed to using supplementary aids alongside the maps. The thesis aims to improve map readers attention and comprehension.

This work is motivated by the concept of mapping stories designed by Mocnik and Fairbairn (2018) in their publication which they termed "story focus" where maps are modified to incorporate the various aspects and characteristics of a story in a map representation. The concept design proposed to modify maps to tell stories of places beyond their spatial context but also emphasize structural aspects like perception, atmosphere, scale and multiple scales as the stories unfold. This research will be implementing story focus as a concept and gain empirical knowledge of its effectiveness in communicating a story compared to its text version.

1.3. Target Research Innovation

Several interactive multimedia and conventional story maps exist on the Internet with most transporting text media alongside the map instead of incorporating the different aspects of the story narrated in the map. Until now, there has only been proposals, methodological frameworks, and conceptual designs on transferring the characteristics of text into cartographic representations.

The innovation this research aims at is assessing the effectiveness of incorporating the characteristics of text in creating a cartographic representation for narrative storytelling.

1.4. Research Objectives and Questions

1.4.1. Research Objectives

The main objective of this research is to implement and subsequently, test the adaptation of conventional cartographic maps to incorporate narrative text in telling stories. The objective is divided into the following sub-objectives:

RO1. Explore existing web mapping frameworks and implement a story in a single cartographic representation by incorporating the structural aspects comparable to the ones often found in narrative text.

RO2. Determine the effectiveness of modifying conventional maps to incorporate characteristics often found in the narrative text by empirical experiments.

1.4.2. Research Questions

RQ1: Which technical means can practically be used to design a cartographic representation that conveys the narratives of a story?

RQ1.1. What web visualization techniques can be used to tell stories of places of interest and at different scales as the story unfolds?

RQ1.2. What web mapping frameworks exist that support representation of the narrative aspects and characteristics (atmosphere, mood, scale, time and spatial context) of a story?

RQ2: What is the reader's perception of the cartographic representation compared to the text version?

RQ2.1. How effective is the implemented cartographic representation in communicating and engaging the reader when compared with reading a text version of the story?

RQ2.2. In which ways do the readers need to adapt to these new techniques of mapping stories?

RQ2.3. Which reactions did the readers perceive while reading the cartographic representation of the story?

1.5. Thesis Structure

The summary of each chapter of this thesis is outlined here. The research consists of 6 chapters.

- **Chapter 1**: The research context, motivation, objectives and questions are described in the current chapter – chapter one. The thesis method workflow is also summarized here.
- **Chapter 2**: Chapter two reviews relevant literature by researchers and the current state of storytelling using maps, the proposed story focus concept, as well as the definition of terminologies. The concept, types and purpose of maps are highlighted. This section of the research elaborates on the map-types using different media and approaches to communicate to its readers.
- **Chapter 3**: This section of the research outlines the techniques and tools for implementing the narratives of a story using the story focus approach are explored. A story is then implemented. Some of the thesis research questions are answered here.
- **Chapter 4**: In the fourth chapter, the experimental design and procedure are elaborated. Following the completion of the experiment layout, the next section, chapter five, presents the results and findings.
- **Chapter 5**: Here, readers perception of the cartographic representation is evaluated from the experiment for effectiveness and focus retention in communicating the story compared to the text version. In this section, the remaining research questions are answered.
- **Chapter 6**: In the last chapter, conclusion, the most relevant findings of the research, as well as the limitations and recommendations for future research, are outlined.

1.6. Thesis Method

Figure 1-3 below summarizes the methods that will be taken to answer the research questions. To evaluate the effectiveness of telling stories using the story focus concept, the aspects and characteristics of a selected story are extracted, and then appropriate visualization techniques to convey the story are explored. Suitable web mapping frameworks and tools are then selected. Reader experiments where participants read the cartographic representation of the story and the text version are then carried out. Results of the experiments are further used to gain valuable insights. Extensive details are presented in Sections 3, 4 and 5 with the conclusions in Section 6.

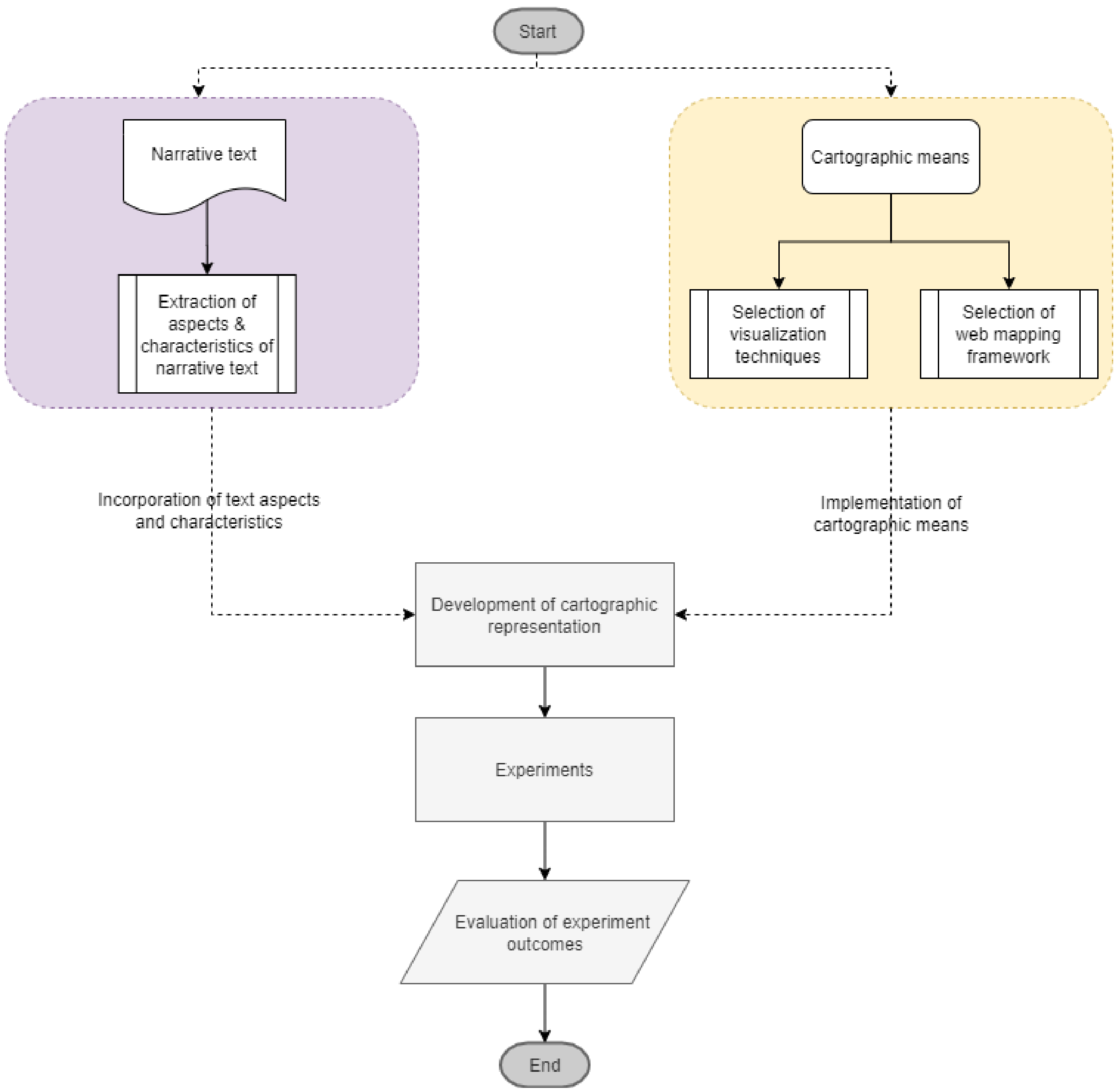

Figure 1-3. Research method workflow.

2. LITERATURE BACKGROUND

This chapter examines the scientific background on the role of maps in telling stories. Chapter 2.1 discusses maps and map types. The next, chapter 2.2 takes a dive into storytelling where the two forms of storytelling, digital and non-digital storytelling is examined. Chapter 2.3 focuses on narratives, narrative text and narrative cartography. While chapter 2.4 discusses story maps and popular tools for creating them. Finally, chapter 2.5 summarizes the concept of story focus and contrasts maps and text.

2.1. Maps

In this section, an overview of maps and map types is researched. The two common map types, paper and digital maps are covered in terms of medium and relevance.

2.1.1. Overview of maps

Maps are used for varying purposes, including depicting geographical processes and human phenomena (Kraak & Fabrikant, 2017). In terms of visualization, maps are considered landmarks of innovations that convey events and processes of places. They present, graphically, the geospatial information that relates to the Earth, its inhabitants and its environment, including metaphysical information (Fairbairn et al., 2001). While map readers are saddled with the responsibility of decoding embedded information of a place in maps, mapmakers must strive to design maps that effectively encode this information (Tateosian et al., 2019).

In facilitating at-a-glance comprehension of spatial patterns and processes, maps should be well designed, engaging and interesting (Kraak & Fabrikant, 2017). Maps should be engaging enough not only to reveal trends but also make the world a better place, such as in achieving the United Nations SDGs objectives (Kraak & Fabrikant, 2017). The data used, needs to be unambiguous, clear, complete and as accurate as possible so that they are not incomprehensible (Stern et al., 2016).

2.1.2. Map Types

Maps are produced to be relevant to society. Therefore, the need to continually innovate how they are made is crucial. The flexibility of Cartography as a discipline means that it will be able to adapt to societal and technological changes in producing maps that are relevant to society. In ensuring that cartography does not experience stagnation, while still maintaining the core cartographic values such as symbols, it involves other cognate fields including artists (graphic designers), scientists (data scientists and visualizers) and technologists (digital media). The volume of data today makes a demand on the modern-day cartographer to acquire programming, and database management, processing and analysis skills to correctly handle the heterogeneous nature of the data from different sources. (Kraak & Fabrikant, 2017)

2.1.2.1. Paper maps

Paper maps are sometimes referred to as traditional maps. They are simply maps for "printed communication" (McKee, 2017). Paper maps are so easy to use, unlike digital maps, because they do not require any special training to use the media. The graphical abstraction of the vast expanse of space is well known to people because of paper maps.

Paper maps are still trendy today, for example, in the tourism world as they are usually incorporated in guidebooks to help tourists and adventure seekers navigate their way and plan their schedule (Mocnik & Fairbairn, 2018).

2.1.2.2. Digital maps

Technology has significantly improved how information is being shared around the world, and Cartography has benefited from these developments. Numerous maps can be found on the Internet including the Web, mobile devices and enterprise systems. These maps aid decision making, provide location services and serve as a guide for tourists and logistics personnel and a myriad of ways.

One of the most popular digital maps is those with multimedia components. Multimedia has extended the reach and products of cartographers (Cartwright, 1999; Cartwright & Peterson, 2007) by creating digital maps that are supplemented by media such as videos, text, sound. Multimedia elements have also enriched how geographical information is presented and interacted with (Mocnik & Fairbairn, 2018). Today, multimedia maps abound over the Internet and are very popular in the journalistic world.

WebGIS, also known as Internet GIS, has provided governments and agencies to serve spatial information via an interactive interface (Chang & Park, 2006; Zhao & Chen, 2017). End-users do not need to install GIS software on their computers, nor do they need to have the data stored and can query for information in near real-time. Many governments use WebGIS to communicate to its citizenry (Milson, 2006). Schools, restaurants and many other services use WebGIS too. This digital mapping technology is so versatile that it allows for operations such as querying for location-based results.

The accessibility and user-friendliness of digital maps are such that even non-geographers can easily use it to derive the information that they are intended to provide.

2.2. Storytelling

Generally, a story is a series of actions that reveal human traits; sometimes, stories are about objects but yet contain qualities of humans (Levine, 2011) while storytelling is the narrating a tale (Dujmović, 2006) or the series of events. Storytelling is as old as human history (Sam Slater, 2020; Yılmaz & Ciğerci, 2018) and has been used for the preservation of cultures (Kocaman-Karoglu, 2015) and improving communication skills (Mokhtar et al., 2011).

Storytelling is an age-long tradition of describing events in such a way that the audience is able to conjure mental images, thus, entrapping them. It is recognized as one vital form of communication. However, advancement in digital media presents new opportunities in telling stoies for the purpose of education, entertainment, marketing, culture preservation, and much more (Levine, 2011).

Lee et al., (2015) in their "Visual Data Storytelling Process (VDSP)" came up with three broad stages for telling stories from data starting with data exploration, story formulation and then telling a story as shown in Figure 2-1. The data exploration stage includes creating sketches to make excerpts. The data excerpts collected are then used to form a rich and compelling plot from which a story is then delivered. Worthy of note is that the storytelling process is rarely linear, that is, at the "make a story" stage, it might be necessary to go back to the data exploration stage to gather more excerpts. The entire story visualization process may or may not involve multiple individuals or roles.

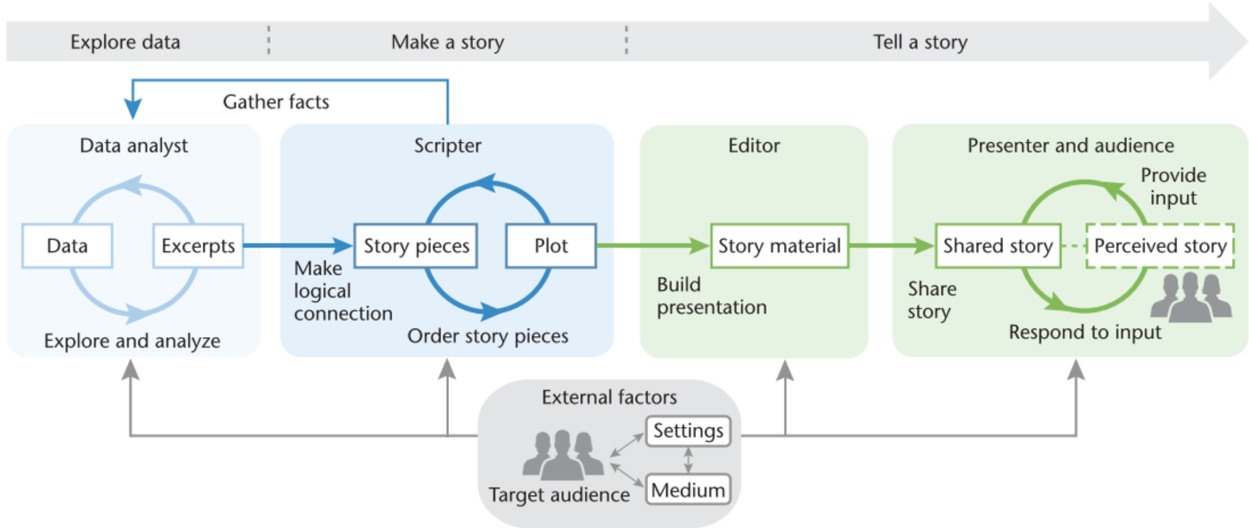

Figure 2-1. The process of storytelling from data (Lee et al., 2015).

Storytelling has a diverse application, both digitally and non-digitally for education, entertainment, advertising, marketing, literally in every form of communication that humans are involved. In the next sub-sections, 2.2.1 and 2.2.2, digital and non-digital storytelling is explored.

2.2.1. Digital storytelling

Today's digital technologies ensure the conservation of the old tradition of telling stories (Hennig et al., 2015) as well as facilitate literacy learning for students and educators (Robin & McNeil, 2019). The use of digital technologies to tell stories do not replace the historical tradition via word-of-mouth but instead brings in new dimensions. Web-based storytelling opens possibilities for creativity and reach (Levine, 2011) and are just are a blend of traditional storytelling and new age technologies (Kocaman-Karoglu, 2015). Digital media has created the opportunity for controlled and interactive visualizations (Lee et al., 2015).

The use of digital cameras, computer software programs and computers to create stories is also referred to as digital storytelling (Meadows, 2003). Meadows (2003) noted that digital storytelling is internet publications of people's experiences. Telling stories via digital media may not come off as easy but can be learned. A key feature of digital stories, however, is that they must be as succinct as possible to avoid boring the audience. Moreover, not all stories on the Internet are original to the authors but are edits. Digital storytelling is a tool, and much more – a revolution.

According to Poletti (2011), there are seven essential ingredients for digital stories: point and point of view, drama, emotion, economy, pace, the gift of voice and quality soundtrack. The first, point of view, helps in the 'realization' of the story; the viewpoint also makes easy personalization of storytelling in a digital medium; the element of drama brings in engagement for the listeners or viewers as it were. Drama helps the audience perceive the structure of the point of view strongly and not casually. Both drama and point of view define the quality of digital stories.

Emotion takes the place of holding the listener's attention. The emotion of the loss of a loved one and loneliness, are characteristics of a story that makes it intelligent and grips the audience but must be used in moderation as it can be manipulative. Point of view and emotion give context to the influence of the gift of voice of the narrator in telling a story.

Economy and pace are formal characteristics that expose digital storytelling as a multimedia technique. Economy refers to the management of space for text, images and other multimedia in a way that facilitates understanding. Good stories preserve space for consideration of its listeners.

Figure 2-2. Digital storytelling in education. (Robin, 2008)

Storytelling is a strong tool that continues to impact several domains in the digital era. Marketers have benefited from storytelling to narratively convey and persuade their clients (Van Laer et al., 2018) and customers alike. Advertising companies have also been able to reach their target audience faster and broader (Elías Zambrano, 2018). Government agencies are not left out, as they have used digital storytelling to create cultural awareness (Baldasaro & Maldonado, 2014). Also, in the identification of development in a specific demographic and age-group (Anderson & Mack, 2019) and in influencing their behaviours (Sawyer & Willis, 2011).

2.2.2. Non-digital storytelling

Only until the advent of digital media, storytelling was mostly traditional, in particular, oral. Yılmaz & Ciğerci, (2018) posit that storytelling is as old as human understanding. They also see storytelling as the human ability to comprehend as it transports the concept of “relocation”, meaning the ability to make known, events that happened in a different place and at a different time known. Non-digital storytelling through the oral narration of past events exists in different genres, including legends, myths, fairy tales and epics (Brown, 1986).

While some think that traditional storytelling as a research approach is ineffective and unsuitable for information gathering, Datta (2018), affirms otherwise. Datta (2018) researched on traditional storytelling and discovered that traditional storytelling provides a platform for original perspectives that could shape how research should be approached, the ethics and methodology. The research further outlines how Western research methods and thinking pattern is unlikely to be useful when dealing with Indigenous communities because it suppresses inclusion, understanding and trust.

Telling stories orally is unlikely to go away anytime soon as it is a good source of information gathering and cultural integration.

2.3. Narratives

Narratives are designed to entertain its audiences rather than cause arguments by minimizing opportunities for counter-arguments (Zwarun & Hall, 2012). They are capable of sweeping readers to different geographies and times (Green, 2014) and connecting cultures to physical spaces (Couling et al., 2019). A compelling narrative is adept at holding the attention of its readers that they do not realize that time has passed nor notice activities going on around them in their immediate environment (Green & Brock, 2000; Green, 2014). Green (2014) called this phenomenon "transportation into a narrative world".

One of the most common forms of digital storytelling is the narration of personal experiences – personal narratives (Robin, 2008). Because these narratives are unique to an individual, they are acquired through face-to-face interviews. Narratives that are personal can be useful in bringing the lives of pupils into the classroom, thereby bridging the gap between schooling and literacy (Kahveci & Güneyli, 2020). As an example, Kourti (2016) successfully explored the utilization of personal narratives in the identification of multiple identities within the context of an organization.

Another type of digital storytelling are stories told to pass on information or instruct (Robin, 2008). This type of narrative is used by teachers to instruct pupils on subject-areas like art, science and technology. An example will be digital stories created to direct students on how to create and use a pendulum in a Physics laboratory. In some instances, personal narratives may also contain historical information as a precursor.

Historical narratives are yet another type of storytelling approach. The most use of historical narratives is in the definition of national identities and the establishment of shared goals for the future (Korostelina, 2019). In a classroom setting, photographs, newspapers and other materials serve as rich sources of events that took place in the past (Robin, 2008). Korostelina (2019) posit that four mechanisms, *recognition*, *assessment*, *connotation* and *prescription*, give historic narratives their normative function.

Narrative persuasion is a predominant technique used in marketing research. The marketing industry uses narratives to tell stories that influence the mental state of their consumers, thereby, mitigating their propensity for rebuttals by arousing their emotions (Van Laer et al., 2018). In an experiment conducted by Appel & Richter, (2007) to test the "absolute sleeper effect", they observed that information gotten from narratives could easily find its way into the listener's real-world knowledge. They also added that transporting stories via narratives to target markets goes beyond the moment they encounter the narratives, but even long after they do.

"Fictional narratives often exist to entertain" (Zwarun & Hall, 2012). Kids enjoy entertainment, especially those show on television. Moyer-Gusé et al. (2010) explain how fictional narratives could be used to entertain kids while still providing information that promotes healthy habits and good behaviours. Beyond entertainment, fictional narratives substantially impact readers' view of reality and beliefs, especially when its content is fact-related (Appel & Richter, 2007; Green, 2014).

In summary, narratives are used in literally every aspect of life and the plot, emotions, locations, media and other materials, when properly utilized, can influence the readers' beliefs, motivation and decisions.

2.3.1. Narrative text

A narrative text is a written, meaningful series of events (Latifa & Manan, 2018). It is a story that tries to resolve problematic events or amuse or entertain its readers (Aris Munand, 2013). Readers generally tend to observe a text in five (5) unique dimensions which are place, cause, time, cause and effect, and character(s) (Zwaan et al., 1998; Therriault & Raney, 2007).

Languages, like English, are characterized by a generic structure. The generic structure of a narrative is divided into five broad categories: *orientation*, *complication* (events sequence), *resolution*, *re-orientation* and *evolution* (Sulistyo, 2017). *Orientation* is the main contention of the text where the character is made known. The *complication* is the middle of the story, which shows the story's sequence. *Resolution* is where the problem encountered by the character is resolved while re-*orientation* contains the moral values intended to be passed on. Finally, the *evolution*, which can be merged with *orientation*, gives information about place and time.

Below is an example of a narrative text titled "A Countryman and a Snake".

> "A countryman's son stepped on a snake's tail accidentally. The tail suddenly turned and hit him so that he died. The father was very angry so that he cut off part of the snake's tail. Then, the snake in revenge stung several of the farmer's cattle. It caused him great loss. However, the farmer decided to stop the fight with the snake. He brought food and honey to the mouth of its lair, and said to it, "Let's forget and forgive. Perhaps you were right to punish my son, and take revenge on my cattle, but surely, I was right in trying to revenge him. Now that we are both satisfied, why should not we be friends again?" "No, no," said the snake. "Take away your gifts. You can never forget the death of your son, nor I the loss of my tail. Injuries may be forgiven, but not forgotten." " – (Ophie Ovie, 2012)

The quality of narrative text will continually play an essential role in telling stories on how humans perceive reality and understand the past. By quality, this means coherence, richness and structure (i.e. the level of organization) (Chen & Liu, 2019).

2.3.2. Narrative Cartography

The geography of narratives is a subject that many studies have given attention to over the last few decades because everything happens in a place. Location constructs, progression and movement, are vocabularies that are associated with stories and lives. In narratives and works of literature, it is almost ubiquitous to find critical vocabularies that stem from spatial models. In most cases, time is emphasized while the location is marginalized and this is in part due to the nature of narratives which unfolds with time (Linton, 2001; Ameel, 2017; Westerholt et al., 2020).

Places play a significant role in the plot of a story, just as stories are crucial in identifying places. Furthermore, this gives narrative cartography a dual role of identifying the spatial structure of a story as well as the impact of stories on places. Although placing narratives on a map might seem as easy as inserting a point, but this is not all there is to narrative cartography. There is the need to include all dimensions of a narrative: place (geography), geometry and time for compelling storytelling (Sebastien Caquard & Fiset, 2014).

Mapping narratives comes with its challenges. One of such is breaking the narratives into bits and pieces of places to resolve the complexity in identifying their actual location (e.g. fictional narratives). Another challenge in mapping narratives includes piecing of places and the relationship between those places from the pieces in the data acquisition phase. In addition, mapping the temporal aspects of narratives can prove challenging especially that both geometry and geography will also need to be linked (Sebastien Caquard & Fiset, 2014).

Couling et al. (2019) observed that contributions by citizens in the development of cartographic representations could help in the capture of esvents of the past while providing future visions. The author noted that narrative cartography through alternative information gathering could equally aid the process of innovative planning.

Expressive creativity is an essential ingredient in the writing process of a narrative text (Méndez-Negrete, 2013) and so also is creativity important for every map design process. Maps produced using narrative cartography techniques, when done creatively, can help its users understand complex landscapes and detect locations more intuitively.

2.4. Story Maps

Like most maps, story maps tell stories. The stories can be that of an event, a journey or a metamorphosis. They help reveal, propagate and explain (ESRI, 2012) information that will be otherwise hidden.

A story map is a visual representation that enables readers to identify, organize and analyze the elements of a story (Stetter & Hughes, 2010) and its grammar (Boulineau et al., 2004). The elements of the story represented on a story map are prompts that support readers in locating and identifying important information (Stetter & Hughes, 2010) while the story grammar refers to the characters, the context and episodic events (Stein, 1975). A story map, besides improving the comprehension ability for its readers, also contributes to how well and much the readers can recall the story content.

Students with or without reading disabilities have also found the comprehension of narrative text enhanced via story mapping visual strategy (Boulineau et al., 2004; Stetter & Hughes, 2010) very helpful. A sizeable number of students with Learning Disabilities (LD) experience reading comprehension problems (Proctor et al., 2007) in studying their curriculum. In an experiment conducted by Narkon and Wells (2013), they demonstrated how the story-mapping strategy improved the comprehension ability of students with reading disability.

Virtually every story map contains the narrative aspect, the textual elements, location data, supplementary media and cartography. These maps are created either to locate something, provide navigation, tell about a place, highlight a topic with geography embedded in it, summarize a situation, compare themes or places, display change with respect to time, model the future or even enable participatory tasks (ESRI, 2012).

An example story map created to tell about the history of China is captured in Figure 2-3. The visualization incorporates several multimedia cartography techniques to communicate the development of China from its early days. The timeline narrated on the history of china in five themes: Early China, Tang Dynasty, Ming Dynasty, Qing Dynasty and Modern China. For each of these periods, a map with markers is shown. A popup feature is attached to the styled markers to provide additional information. The popups contain a picture and some text for a descriptive title. Clicking the image opens up more to be read in a larger popup widow with more text. Videos are also used to provide additional aid to visitors of the digital story map to enhance their understanding of China's rich development from its early dates until modern-day China.

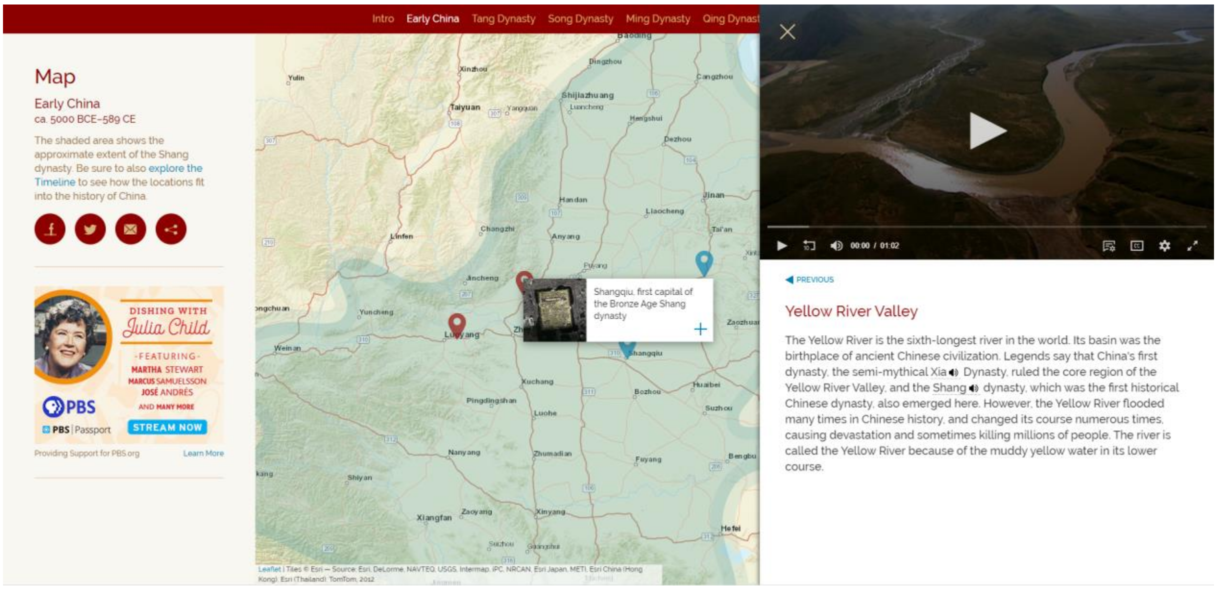

Figure 2-3. Story Map of China. (Source: The Story of China, Public Broadcasting Service (PBS, 2017))

ESRI story map is perhaps the most famous story maps in the industry today. The team at ESRI continuously explores ways to deliver digital maps with new capabilities to engage and inform its users uniquely. Three key reasons why ESRI went in for the development of story maps was to enable individuals to create and publish their personal stories, to put on display, the usefulness and importance of geographic information and to showcase how powerful ArcGIS as a platform is in communicating narratives (ESRI, 2012). Tons of templates and instructions are available to begin the process of making a story map. The story maps are a combination of intelligent maps and web maps.

StoryMapJS is yet another popular tool used to create online story maps. It is an open-source tool that is free to use. It allows for the integration of custom styled maps hosted on map services like Mapbox. A slider is used to move through different locations to narrate a story in a sequence as they occur. The tool was developed and is continually maintained by the Northwestern University Knight Lab who develop media solutions that are an intersection of technology, design and storytelling.

Besides, ESRI story map tool and StoryMapJS, story maps can be created with a combination of open-source tools and technologies and deployed over the Internet. The possibility becomes limitless as technological innovations continue to increase.

2.5. Story focus Concept

Mocnik & Fairbairn (2018) proposed a novel approach in modifying map structures to tell stories more effectively. Their method is a deviation from the current pervasive way of narrating stories using additional multimedia elements alongside a map. They posit that, so far, multimedia story maps, despite being interactive, have not sufficiently transferred the same qualities of texts in telling stories to maps. Their approach also aims to capture the map reader's focus.

The concept, story focus, which enhances the ability of maps to communicate the same information in narrative text on a map was developed by Mocnik & Fairbairn (2018). It involves the incorporation of the structural features of texts such as time, non-spatial relations, emotions, atmosphere. Unlike the popular maps produced today, story focus makes provision for a more dynamic representation of important elements in a story's narrative by implementing the structural elements of text versions of a story. The approach makes a shift from today's paradigm of map use and feature interpretation by differently interpreting existing concepts.

The heart of representations using the story focus concept means depicting what is relevant to the story and eliminating redundancies. However, as the story unfolds, the map and its elements can change with time. The authors of this concept likened this approach to a "variable generalization technique" where the cartographic visualization is designed to be adaptable using varying layers of mood, emotion, component features, scale and level-of-detail.

2.5.1. Map versus text representations

Mocnik & Fairbairn (2018) acknowledge that while conventional maps are being explored to incorporate the characteristics of a narrative text, this may not be entirely feasible. Some of the affordances of text that may be difficult to incorporate in a map accurately include the atmosphere of the location where the event took place. Text can easily tell what the characters were doing, where they were, how they feel and relate to one another, whereas a map is limited in conveying the same features of a place because they are non-spatial. Zupan & Babbage (2017) research revealed how narrative text help readers understand emotions easily. Table 1 summarizes a comparison of the properties of prototypical textual and cartographical representations.

Table 1. An overview of similarities and dissimilarities between maps and text media. (Source: Mocnik & Fairbairn, 2018)

Map	Text
Two dimensions	One dimension
Parametrized by space	Parametrized by time
Spatial relations implicitly contained	Spatial relations need to be explicitly represented
Size of the representation of all binary spatial relations is $O(n)$ for n objects	Size of the representation of all binary spatial relations is $O(n^2)$ for n objects
Spatial incoherencies and contradictions impossible	Spatial incoherencies and contradictions possible
Strong spatial context	Strong temporal and thematic context
Limited flexibility of the scale	The high flexibility of the scale
Closed-world assumption	Open-world assumption
Possibly animated	Static
Can be perceived in arbitrary order	To be perceived in a contemplated order
Inflexible use of categories	Flexible use of categories
More objective	More subjective use possible

Implicit Spatial Index	No implicit spatial index
Algorithmic generalization possible	Algorithmic generalization hardly possible

3. STORY VISUALIZATION

In this chapter, I report how I implemented the story focus concept with the story, "Legend of Meng Jiangnu". The selection of the story is described in Section 3.1. The techniques and technologies needed to implement the narratives of the story in a cartographic representation are outlined in Section 3.2. A prototype of the story visualization is designed before the actual development of the map.

3.1. Story

The story, "*Legend of Meng Jiangnu*", is one of the popular folktales in the People's Republic of China. The story has variations in terms of content as well as the title. The multiplicity of versions and variations in the Chinese tale is linked to retelling via the agelong tradition of oral storytelling and performance. In addition to the subtle nuances in story retelling, translation from Chinese to English contributes to the variation in folktale.. However, the plot and theme remain unchanged. The first translation was done by George Carter Stent, who lived his adult life in China and had a predilection for Chinese tales. George's version is included in a compilation by Lu Gong as "*Mêng Chêng's Journey to the Great Wall.*". About fifty years on from George's version, in 1934, came another translation by Geoffrey Chen and Genevieve Wimsatt translation which they titled "*The Lady of the Long Wall*" (Idema, 2018).

For this research, I created a minified version of the story. The minified version here refers to the part of the narrative which starts from when the main characters, Fan and Meng, lived in different places to when they meet, and then finally, Meng seeing Fan's body remains as bones. The three online versions used to create this short version are:

i. *Meng Jiangnu Cries The Great Wall* [1]

> "More than 2000 years ago, there is a couple, Fan Xiliang and Meng Jiangnu, get married. During their wedding day, the government comes to their home and takes Fan away, for the labor force of building the Great Wall.
>
> Meng loves her husband so much, so she overcomes so much difficulty and finally finds part of the Great Wall where her husband worked. At the same time, she hears a bad news that her husband is dead because of exhausted to build the Great Wall. She is so desperate and cries three days on the Wall. Suddenly, the Wall collapses 800 kilometers, and she can see her husband's bones."

ii. *Meng Jiangnu's Bitter Weeping* [2]

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[1] *Meng Jiangnu Cries The Great Wall.* http://www.beijingwalking.com/top-5-most-famous-chinese-stories/

[2] *Meng Jiangnu's Bitter Weeping.* https://www.travelchinaguide.com/china_great_wall/culture/mengjiangnu.htm#:~:text=The%20Great%20Wall%20story%20of,bottle%20gourd%20in%20his%20yard

"Meng and Jiang liked this good-looking, honest, and good-mannered young man. They decided to wed their daughter to him. The two young people accepted happily and got married several days later. However, three days after their marriage, officials suddenly broke in and took Fan Qiliang away to build the wall in the north of China.

It was a hard time for Meng Jiangnu after her husband was taken away - she missed her husband and cried nearly every day. She sewed warm clothes for her husband and decided to set off to look for him. Saying farewell to her parents, she packed her luggage and started her long journey. She climbed over mountains and went through the rivers. She walked day and night, slipping and falling many times, but finally she reached the foot of the Great Wall at the present Shanhaiguan Pass.

Upon her arrival, she was eager to ask about her husband. Bad news came to her, however, that Fan Qiliang had already died of exhaustion and was buried into the Great Wall! Meng Jiangnu could not help crying. She sat on the ground and cried and cried. Suddenly with a tremendous noise, a 400 kilometer-long (248-mile-long) section of the wall collapsed over her bitter wail."

iii. *The Legend of Meng Jiangnu* [3]

"Once, when she was walking in the garden, she found a man hiding in the bushes, and immediately called for her parents. When the man came out, it was a young, good looking man named Fan Xiliang. Fan was hiding from officials that wanted to take him to build the great Wall. Jiangnu and Xiliang fell in love and were married in short order. But their happiness was not everlasting – three days after their wedding Xiliang was taken by officials to build the wall.

A year passed and Jiangnu did not hear any news from her husband. Once she had a dream that he was freezing on the wall, after waking up she started knitting warm clothes for him. It was then she decided she would find him, no matter the cost. Day and night she climbed over mountains and went through the rivers, slipping and falling many times, and after many moons she finally reached the foot of the Great Wall at the present Shanhaiguan Pass. And when she reached there, it turned out that her husband had died from hard labor and was buried somewhere under the Great Wall like thousands of other workers.

Upon hearing such news Meng Jiang could not help but cry with grief for her beloved husband, she wept like this for three days and three nights.

Suddenly with a tremendous noise, that part of the wall just collapsed. Chinese believed in the telepathy between heaven and man. They thought man's cries could move God, and that's why she was able to "bring down the Great Wall with her tears"."

Based on these three versions, I created the following minified version of the story, which is used hereafter for the study conducted:

[3] *The Legend of Meng Jiangnu*. https://www.theworldofchinese.com/2015/03/the-legend-of-meng-jiangnu/

> "More than 2000 years ago, there lived Fan Xiliang and Meng Jiangnu, who later got married. Three days after their wedding, the government comes to their home and takes Fan away for the labour force of building the Great Wall.
>
> Seeing that her husband was taken away, Meng experienced such a hard time, and she cried for days as she missed him terribly. Meng loves her husband so much, so she takes some warm clothing and departs for the Great Wall where her husband works after a year of not hearing from him.
>
> She finally gets to the Wall and hears the bad news that her husband is dead from exhaustion while building the Great Wall. She is so desperate and cries three days at the Wall. Suddenly, the Wall collapses 800 kilometres away, and she can see her husband's bones.".

Each of the online versions had similar plots and the same characters but differed in level-of-detail. For instance, only the second online resource mentions how many days had passed before the government forces took Fan after his wedding to Meng. Regarding Meng's journey to the Wall to find Fan, both the second and third online resource detailed her packing up warm clothing before setting off for the journey while the first resource gives no such detail. The number of days she spent crying at the Wall was not mentioned in the second but was detailed as three (3) days in the first and last online resources. Similarly, there exist variations in the exact distance of the Wall that collapsed according to the legend.

The difference in versions can be traced to the old tradition of telling and retelling stories by word of mouth. Bias tends to be introduced when a story is orally retold in an attempt to emphasize a detail or pass on a specific lesson which then leaves the listeners transferring the same or less detailed version. Besides, the versions are usually characterized by different wordings.

3.2. Implementation of story

In this section, the story is visualized. The process begins with breaking down the story and matching the narratives with suitable cartographic visualization techniques in 3.2.1, followed by the design of the cartographic representation in 3.2.2, and then the development of the map visualization in 3.2.3.

3.2.1. Cartographic representation techniques

Digital maps are advantageous compared to non-digital maps. Creating cartographic visualizations for the Internet makes it possible to reach a broad audience. An online map could either be static or interactive. Interactive maps are designed to let users change aspects of the map, and thus create a bidirectional relationship between the user and the map, which is in contrast to static maps. Although the latter type of maps are relatively straightforward to create, such maps do not allow users to explore the contents beyond what is initially presented on their screens. Generally, interactive maps on the Internet provide hybrid functionality of exploration and presentation (Smith, 2016).

The process of creating well-designed maps starts with the selection of appropriate visualization techniques (Smith, 2016). A summary table of the techniques that I have chosen for visualizing the story is presented in Table 2. The table shows the entire narrative split into pieces with matching appropriate techniques to convey the story. The main goal of selecting the visualization techniques is to ensure that the characteristics and aspects of the text are transferred to the visualization. The techniques selected were also considered when selecting the tools and framework to be used.

Table 2: Mapping of techniques

Narrative Text	Story Visualization Techniques
More than 2000 years ago, there lived Fan Xiliang and Meng Jiangnu,	- Meng and Fan in different far apart locations on the map screen.
Who later got married.	- Meng and Fan locations are closer and finally merge on the map. - A heart symbol, representing love and continuous wedding animations for joyous celebrations.
Three days after their wedding,	- Government forces approaching Meng and Fan home on the map. - Government forces background map is of dark grey colour to signify aggression and tensed atmosphere.
The government forces come to their home	- Government forces now at Meng and Fan's home on the map. - The background map is now dark grey.
and takes Fan	- Animation to show Fan taken away from Meng by the government forces. - A button to repeat the same animation.
away	- Show Fan taken away by Government forces in a different location with a dark grey map background. - Animate Meng at home, crying in anguish with red map background.
for the labour force of building the Great Wall.	- Show Fan at the construction site of the great wall with the government forces. - Fading grey-to-light opacity animation to signify day and night.
Seeing that her husband was taken away, Meng experienced such a hard time, and she cried for days as she missed him terribly.	- Meng crying at home map location with animated tears. - Continuous clock hands winding to indicate many days.

	- Red background colour to indicate pain and anguish.
Meng loves her husband so much, so she takes some warm clothing and departs for the Great Wall where her husband works after a year of not hearing from him.	- Meng travelling with a bag and a thinking cloud of her husband - Yellowish map background indicating hope to see him.
She finally gets to the Wall	- Meng arrives at the Great Wall. - A yellow light bulb to indicate she gets an idea to ask the Government forces of her husband's whereabouts.
and hears the bad news that her husband is dead from exhaustion while building the Great Wall.	- Government force with speech bubble animation delivering bad news of the death of Meng's husband.
She is so desperate and cries three days at the Wall.	- Two map locations: one where Meng stands where she was told the bad news and the other where Fan was working. - Animation showing Meng's tears and crying aloud. - Fading grey-to-light opacity animation to signify day and night.
Suddenly, the wall collapses 800 kilometers away	- Meng keeps crying aloud and wall in second map location breaks and Fan's bones are revealed.
and she can see her husband's bones.	- Meng goes to the second wall location on the map and sees Fan's bones. - Yellowish map background to indicate relief and hope. - Button to repeat animation of Meng walking to the bone's location on the map.

3.2.2. Design of the cartographic representation

In this section, the process of creating a visualization to convey the narrative of a selected story is presented. Specifically, Section 3.2.2.1 explains the design of the icons, while the layout of the visualization is described in Section 3.2.2.2.

3.2.2.1. Icon design for the cartographic representation

Cartographic representations contain graphic elements such as icons which serve as metaphors of real items they represent. Icons are visual language elements of a map. For computer icons, attention should be given to contrast, identity (metaphor) and uniqueness (that is, should be easy to distinguish). Besides, efficient icons should be able to stimulate the eyes of its users (Honeywill, 1999) while they view them.

To design the elements of the story, both Adobe Illustrator and Adobe Photoshop were used. For the story start screen, a background image (Figure 3-1) was designed in Photoshop. Adobe Illustrator was used to create vector arts that were exported for onward use either as a Portable Network Graphics (PNG) or as a Scalable Vector Graphics (SVG). The PNG format was used when the graphic will be directly integrated as an element of the map visualization while the SVG format was used when the graphic content will be further animated. PNG was preferred over JPEG for its lossless compression technology.

SVGs can be scaled with any loss of quality, which makes them suitable for building applications on the web with different viewports. An SVG is essentially an XML file used to draw geometries and text that is accessible and easy to modify (Drasner, 2017). I exported the SVGs with configurations that will be needed in the latter part of the story visualization programming. In the Illustrator SVG export dialog, the option for Styling was set to *Inline Style*. The reason I chose the inline styling option was to ensure that the attributes were not overwritten at some point by the CSS (Cascading Style Sheets) – a style sheet language used in defining how elements of a web document appear (Wikipedia, 2014). Also, the images option was set to *preserve* to keep in shape and size as designed. Because some graphics are a combination of layers, the Object IDs property is set to the value of *Layer Names*. Hence, the need to have short but descriptive names while creating each layer. “Minify” and “Responsive” were *checked* to ensure that the exported graphics can easily be scaled in different viewports.

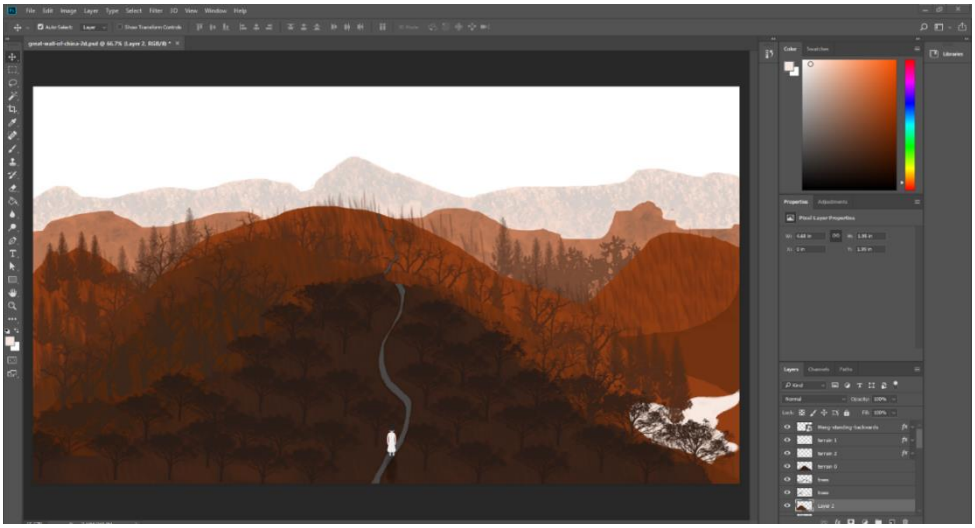


Figure 3-1. Background image design in Adobe Photoshop.

The characters designed in Adobe Illustrator can be found in Figure 3-2. Each character was designed by the use of common metaphors. The protagonist, *Meng Jiangnu*, a lady is designed with a long flowing gown while *Fan Xiliang*, who is a man, is designed wearing a trouser. The *government forces,* who use some form of aggression, is represented as an icon of a person holding a weapon (a gun). Appendix VI contains other icons and metaphors.

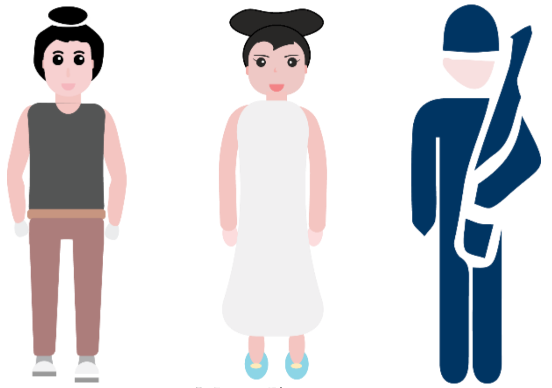


Figure 3-2. Story characters designed in Adobe Illustrator.

3.2.2.2. Layout design of cartographic representation

Prototyping is an essential step to ensuring that the requirements to develop applications and other products are met even before they are built (Bleek et al., 2002). Prototyping is a component of design thinking, and it helps product owners to validate their ideas via experimentally modelling (Joseph Kiipo, 2018). Roth et al. (2015), discussed the importance of starting a user-centred project with a conceptual design to manage resources efficiently. The iterative process creates space for formative feedback, which leads to a smooth and rapid modification of a product at an economical rate. The outcome of the cartographic representation in this research is a result of several iterations.

Figma[4], an easy-to-use prototyping tool, was used to create a mock-up for the story visualization. Figma is a tool to design interfaces, and it is available for use in a web browser and as a desktop application (Joseph Kiipo, 2018). While Figma helped with the formative stage of the story visualization, it also sped up the web development process by providing useful code snippets equivalence of design styles in CSS that were easy to integrate. Each scene of the story was designed as it will look when the actual visualization is completed. Hand sketches are an alternative to using digital tools in prototyping but require extra resources (time and effort) to convert the prototype to actual application development. Therefore, the digital prototyping tool, Figma, was used to save time and effort.

For instance, the story's start page (Figure 3-3) was designed by dragging and dropping self-designed images for the background; the button component is achieved by drawing a rectangle with border-radius to give it well-rounded corners, and by the use of text tool to write the text in the button as well as over the background image. When cliked, the CSS equivalence of each component was provided on the right pane of the tool which significantly accelerated the visualization development phase.

[4] Figma. https://www.figma.com/

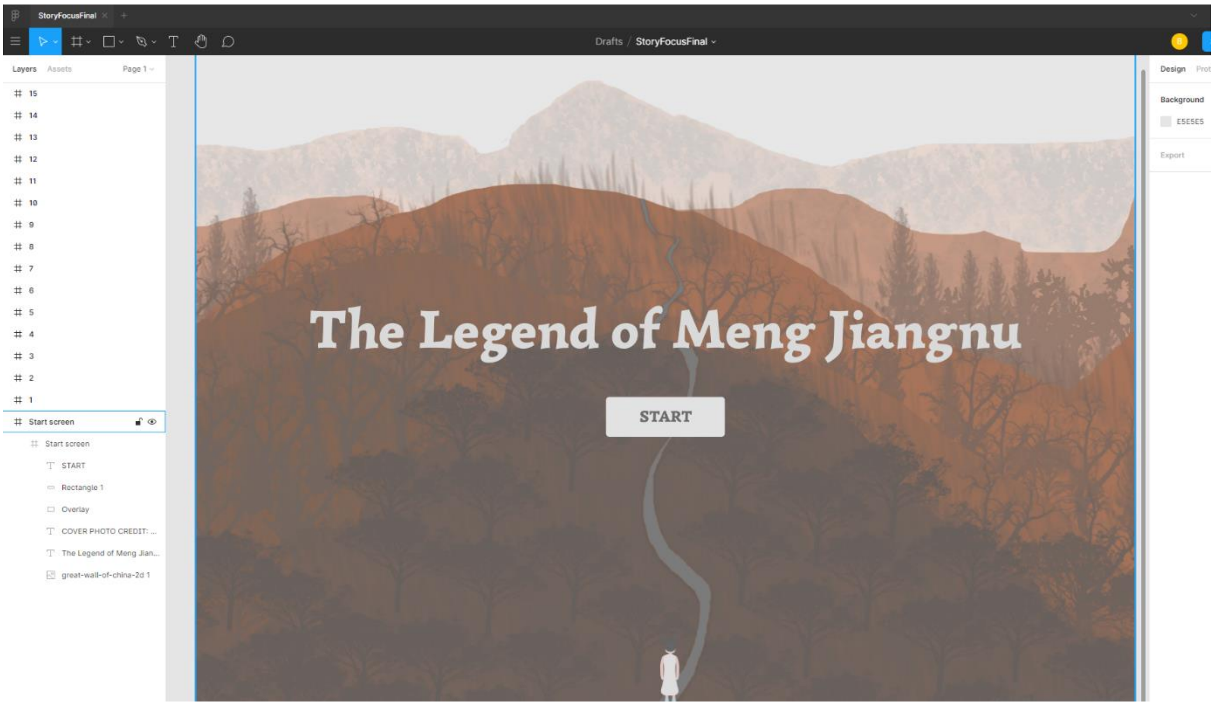


Figure 3-3. Design of start screen in Figma.

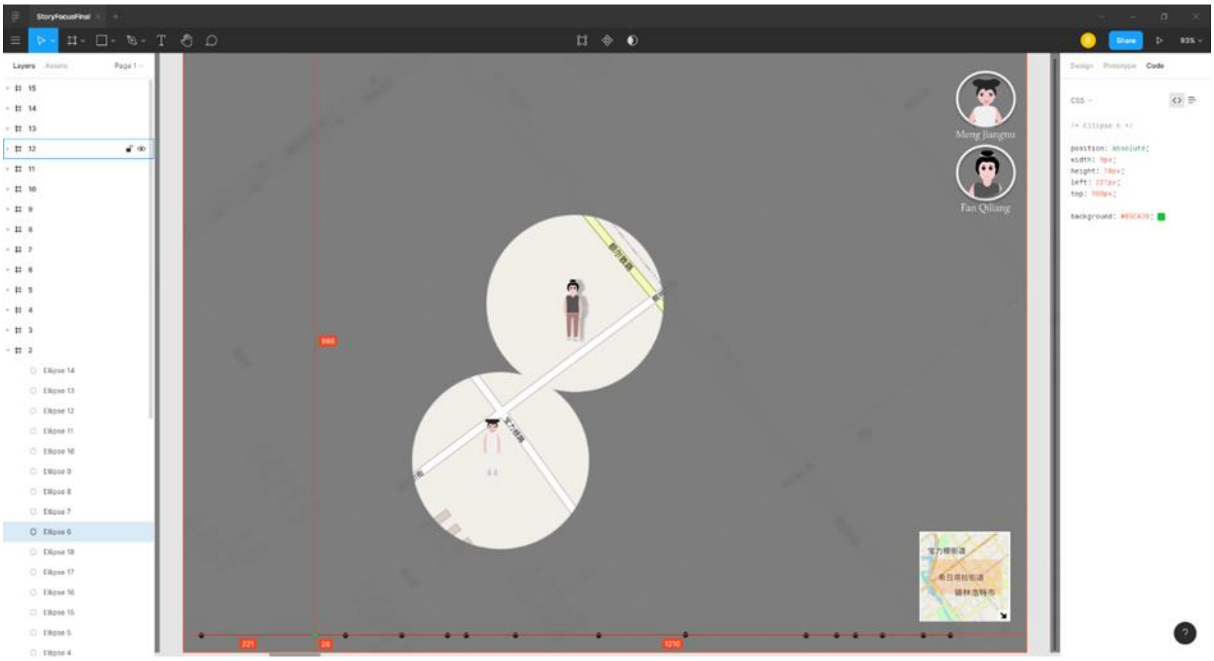


Figure 3-4. Story scene design with CSS style equivalence of a highlighted component.

The next (Figure 3-4) is an example of the design of a story scene using the Figma tool. A saved screenshot of a map is dragged and dropped into the design space. The legend is achieved by masking the image with a circle-like geometry and text to the label. A similar approach was used to reproduce other fourteen (14) scenes.

Prototyping has its limitations. It was challenging to imitate user mouse events for the proposed visualization. What was, however, possible during the conceptualization stage was to lay out the before and after mouse click action, for example. Prototyping still turned out to be very helpful in creating a look-alike of the final story visualization.

Overall, creating a look-alike of the story visualization saved time, optimized coding and validated my initial thoughts. It also aided my selection of tools and libraries for the story visualization.

3.2.3. Development of a cartographic representation

The story focus map for the selected story, Legend of Meng Jiangnu, was developed using open-source technologies. The implication of the use of open-source tools and technologies is that no monetary cost is incurred; however, because individuals build these projects for free, the risk that they might not be maintained perpetually exists. In this part of the research, the resources, tools and technologies used to create the visualization are described. Corresponding screenshots can be found in Appendix VII.

The story visualization is a client-side Single Page Application (SPA). Client-side means that it does not make use of a database to store the application's data, nor does it have a backend server. Furthermore, SPA means that the story visualization itself (not including the start page), is built with a single HTML document that shows different elements (containers) selectively on user interaction. This creates a multipage navigation illusion. The benefit of creating the map visualization as a SPA is that there is no need for the browser to reload the HTML page during navigation but rather preserves its state (Katie Lawson, 2018).

To write the codes for the internet story focus map, the Visual Studio Code (VS Code)[5] IDE is used. VS Code is a lightweight free code editor developed by Microsoft and is available for Linux, Windows and macOS (Rithm School, 2018). The intelligent editor has a large community of extension authors and maintainer that help speed up code debugging and linting.

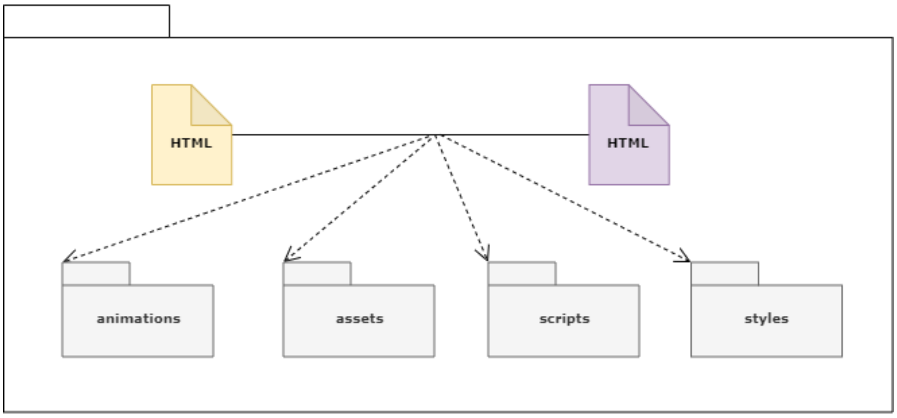


Figure 3-5. Structure of directory.

The file structure was set up in such a way that it is easy to navigate and reference files. Figure 3-5 shows how the project was set up.

[5] VS Code. https://code.visualstudio.com/docs

i. Base directory: This directory houses the base files and resource folders. The two HTML (Hypertext Markup Language) documents are where the structure of the web pages is defined.

ii. Animations directory: Animated SVGs are kept in this folder from where they are accessed by the HTML document(s). The files in this folder have the extension *svg*.

iii. Assets directory: This directory stores all image resources. The files in this folder have the file extension *png*.

iv. Scripts: DOM manipulation is executed via scripts – vanilla JavaScript in this instance. The files in this directory have the extension *js*.

v. Styles: All custom styles to give aesthetics to the HTML document are defined in *.css* files which are stored in this directory.

3.2.3.1. Basemaps

One common feature of most online cartographic representations is a basemap. Several free and hosting maps services exist today on the Internet. However, selecting the right basemap depends on the context and the mapping goal.

Basemaps are grouped into aerial (raster-based), rendered (vector-based) and hybrid (aerial imagery overlaid with rendered data) map types. The two significant factors for choosing a basemap are style and functionality (Michael Moore & Andy Walz, 2016). An aerial basemap shows details of the real world, like a photograph, making it suitable for projects related to natural features. On the other hand, rendered basemaps, a result of digitizing, simplifies the real world mostly contain roads and cities and are used in navigational-related mapping projects.

Several free and paid basemaps exist. An exhaustive list of OSM map tiles from different contributors can be found on Wikipedia Map Tiles page[6] and on Leaflet providers web page[7]. Although most of these map tiles are free-to-use, it is usually mandatory to attribute their source. The map created as part of my MSc research uses the map tiles listed in Table 3.

Table 3. Selected basemap tiles.

Map Tile Provider	URL
OpenStreetMap	https://{s}.tile.openstreetmap.org/{z}/{x}/{y}.png
Stadia maps[8]	https://tiles.stadiamaps.com/tiles/osm_bright/{z}/{x}/{y}{r}.png

[6] Tiles: https://wiki.openstreetmap.org/wiki/Tiles

[7] Leaflet-providers. https://leaflet-extras.github.io/leaflet-providers/preview/

[8] NOTE: This map tile is free only when served over a local network (127.0.0.1) but requires a license when deployed on the Internet. The experiments served the files locally and the need for paid license, before deployment on the internet, was only discovered after the completion of writing this thesis.

The choice of these map tiles was based on the consideration on the level-of-detail desired in the narrative locations on the map canvas and the default map styles. For some map tiles, redundant features (e.g. transportation networks and road levels) and labels were included, which made it challenging to ensure that the map reader can focus on the storytelling elements of the map. The selected map tiles in Table 3, besides the desired level-of-detail, were selected for their default map styles which makes the modification of their colours suitable for transferring the atmosphere of a place.

3.2.3.2. Colours and emotions

Colours are perceived differently by different people. The complex relationship between emotions and colour (Gilbert et al., 2016) requires interdisciplinary research (Mikellides, 2017).

The right colour scheme, contrast and meaning are capable of providing readers with legibility and comprehension with regards to the content intended to be perceived and derived from the visualization (Sterba & Bláha, 2015). Research (Ou et al., 2004; Cameron Chapman, 2010) has shown that colours can be generally categorized into warm, cool and neutral colours amongst other specific categorizations. Warm colours such as (red, orange and yellow) convey emotions like passion, energy, enthusiasm and happiness. Cool colours (green, blue and purple), on the other hand, are calming colours and depict emotions such as quietness, calmness and peace. Neutral colours like brown, black and white are used in relation to warm and cool colours and get their emotion definition based on their surrounding colours.

For the selected story, the map tile colours were based on the result of existing experimental research. Naz Kaya & Helen H. Epps (2004) conducted an experiment involving 98 university students whose emotional responses to presented colours were recorded. The researchers found that the students mostly perceive *red* for anger and love, *yellow* for happiness and excitement, *black or dark grey* for fear, sadness, depression and power, etc. It was based on their research, which multiple resources also linked that the colours were selected for this research.

i. The government forces represent aggression, fear and power, and so the colour selected is *dark grey*.

ii. After the government forces take Fan away from his wife Meng to work on the construction of the Great Wall, Meng was sad and angry, and so the colour selected is *red.*

iii. Lastly, when Meng takes up warm clothing to look for Fan at the Great Wall, that signified happiness, hope and excitement. Therefore, the colour selected is *yellow*. The same colour was used when Meng finds her husband's bones after crying for days on receiving the sad news of his death.

3.2.3.3. Web mapping framework

A web mapping framework can be seen as the engine of an internet map (Michael Moore & Andy Walz, 2016). Google Maps API, Leaflet.js and Mapbox are some of the popular web mapping frameworks. All these frameworks interact with the DOM via scripting, but not all are without a subscription fee. Google Maps API and Mapbox are proprietary libraries, that is, paid-for services and as such, requires a token to validate usage. Leaflet, on the other hand, is an open-source JavaScript framework and is free to use. Other web mapping frameworks include OpenLayers, D3.js, and ArcGIS API for JavaScript.

Besides the fact that Leaflet.js is open-source, I have also selected to use this webmapping framework because it is lightweight and extensible. Leaflet.js is built with JavaScript with a high level of abstraction, that is, not all functionalities are put in the base class but instead only what is necessary which developers can build upon. Its vast developer community build packages and plugins that provide additional custom functionalities to web maps. The small size of the webmapping framework, 39 KiloBytes, impacts the good performance of applications built using it. Mobile cartography projects also use Leaflet.js (Edler & Vetter, 2019).

For this thesis, version 1.0.3 of the Leaflet library has been used. Some Leaflet.js extensions were integrated to realize the techniques designed in Table 2. They are:

I. Leaflet-TileLayer-colorFilter: It is a lightweight plugin for changing map tiles colour. This plugin (v1.2.5) was used on the story visualization map tiles to apply CSS colour filters like that used at grey out the map.

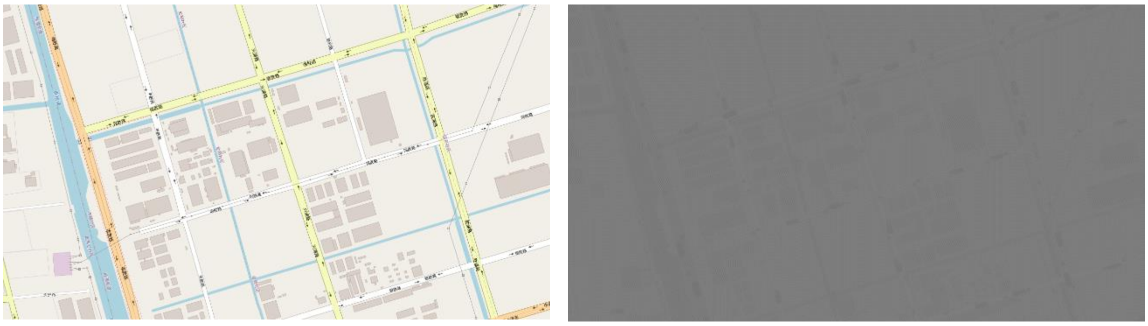
Table 4. CSS filter options for Leaflet-TileLayer-colorFilter map tiles.
(Source: https://github.com/xtk93x/Leaflet.TileLayer.ColorFilter).

Filter	Aliases	Description	Example	Default
Blur	blur	Applies a Gaussian blur filtering measured in pixels	['blur:2px']	0px
Brightness	brightness, bright, bri	Controls the brightness of tile image	['brightness:150%']	100%
Contrast	contrast, con	Changes the color contrast of tiles	['contrast:150%']	100%
Grayscale	grayscale, gray	Changes the color of tiles to a grayscale	['grayscale:100%']	0%
Hue-Rotate	hue-rotate, hue-rotation, hue	Applies a hue rotation in degrees on tile colors	['hue:180deg']	0deg
Opacity	opacity, op	Defines the opacity of the tiles	['opacity:60%']	100%
Invert	invert, inv	Invert the tile colors	['invert:100%']	0%
Saturate	saturate, saturation, sat	Saturates the tile colors	['saturate:150%']	100%

Sepia	sepia, sep	Converts the tile colors to sepia	['sepia:0%']	0%

A base filter was set-up at the top of the JavaScript file to define the level of greyness the main map tile will have. The below code snippet is the filter properties used.

```
let baseFilter = [
    'blur:2px',
    'invert:42%',
    'grayscale:100%',
    'bright:85%',
    'contrast:60%',
    'hue:83deg',
    'saturate:97%'
];
```



(a) Before application (b) After application

Figure 3-6. Before and after applying the defined base filter.

The goal of greying out the map is to keep the map reader's focus on the relevant areas. The colour filters can be generated by tweaking the values, as described here: https://xtk93x.github.io/Leaflet.TileLayer.ColorFilter.updateFilter/.

II. Leaflet-TileLayer-Mask: A lightweight plugin for creating mask effects over map tiles. A circle was designed in Adobe Illustrator to serve as a "story bubble", that is, a focus location on a map where the story narrative currently occurs. The story bubble creates an intended illusion that just the masked area(s) of the main base map is of relevance and other regions (greyed out) are not of current importance. Because the story is a legend with no links to the exact *xy-coordinates* on a map, locations are based on clues in the story's narrative, like "The Great Wall".

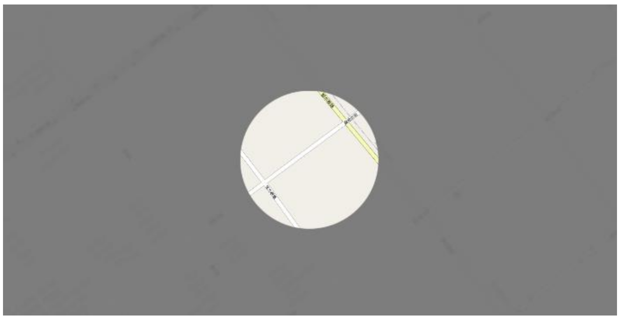


Figure 3-7. "Story bubble" created using the leaflet-tilelayer-mask plugin.

A setback encountered implementing this extension is that with the leaflet zoom in and out functionality enabled, the "story bubble" changes position relative to pixel location on-screen. For this reason, the default map behaviour of zoom control was completely disabled both on double-click and via the scroll wheel.

The plugin can be found on the author's GitHub page: https://github.com/frogcat/leaflet-tilelayer-mask.

III. Leaflet-MiniMap: Mini-maps were needed to provide additional context to the location of the story. The plugin (v3.6.1) used was developed for this exact purpose, where the map zoom level can be fixed at a value higher than that of the main map and the map reader can view labels of the main map at a higher level of generalization (e.g. city, country). The mini-map serves as the locator map. The leaflet extension can be found on GitHub where the author makes it available: https://github.com/Norkart/Leaflet-MiniMap.

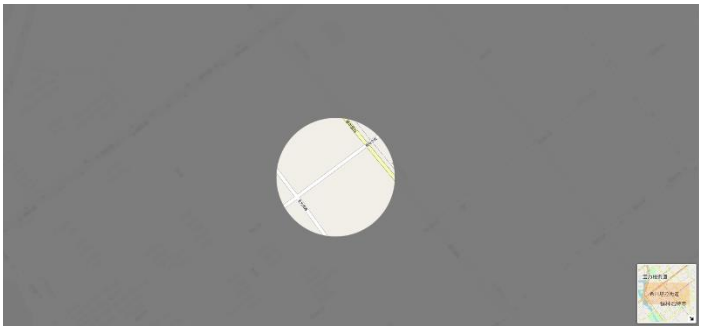


Figure 3-8. MiniMap at the bottom right-hand corner of the screen.

IV. Leaflet-AnimatedMarker: Stories are usually characterized by movement in space. The goal of using the Leaflet-AnimatedMarker plugin is to move characters in space along a geographic path. Version 1.0.0 of the plugin was used on marker objects along polylines via CSS3 animations. It works by defining the points (*xy-coordinates*) in space from-and-to that a marker should move at a rate in meter per milliseconds. However, the original codebase was modified to restart the character movement by the story visualization reader with the click of a button. The original codebase can be found on GitHub (https://github.com/openplans/Leaflet.AnimatedMarker).

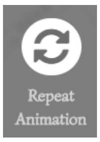
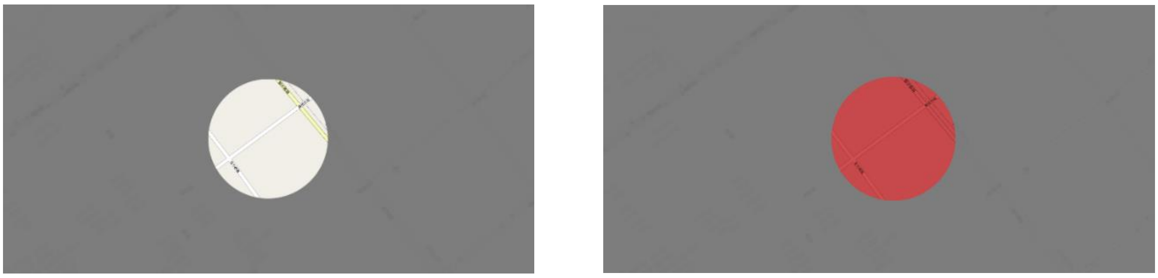


Figure 3-9. Animation button to restart the movement of characters.

Furthermore, some default functionalities of Leaflet.js were used to modify the map to convey characteristics of the text narrative such as the atomosphere (including mood and emotion) of an event. One of these features is the creation of custom panes. Leaflet map tiles are built as a group of panes. The panes allow for edits of map CSS properties such as *z-index*, *pointer events*, *filter*, *animations*.



(a) Before application (b) After application

Figure 3-10. Before and after application of custom vanilla CSS filter.

It can be observed from Figure 3-10 that the colour filter applied in the story bubble changed from the default bright map tile in (a) to a red map tile in (b).

Why use vanilla CSS colour filters at some point and not continue with the Leaflet-TileLayer-colorFilter? The answer to this lies in the limitations of the SVG mask(s) used to create the "story bubble". The Leaflet-TileLayer-colorFilter extension is unable to manipulate the SVG masks directly except in Firefox browsers (Figure 3-11); hence, there was a need to create custom panes and then modify their CSS properties. Other instances where custom panes were used was in the creation of a fading transition animation by changing the opacity values to indicate day-and-night in the story visualization. CSS vendor prefixes (e.g. *-o-* for Opera, *-moz-* for Firefox) were implemented to ensure compatibility with frequently used web browsers.

	Chrome	Edge	Firefox	Internet Explorer	Opera	Safari	Android webview	Chrome for Android	Firefox for Android	Opera for Android	Safari on iOS	Samsung Internet
`filter`	53	12	35	No *	40	9.1	53	53	35	41	9.3	6.0
On SVG elements	No	No	35	No	No	No	No	No	35	No	No	No

Full support

No support

* See implementation notes.

User must explicitly enable this feature.

-x- Requires a vendor prefix or different name for use.

Figure 3-11. CSS filter browser compatibility. (Source: MDN web docs)

Other default Leaflet.js features used include *leaflet image overlay* to position images at a specific bounding box and *leaflet marker* to places markers at desired geographic locations. Both default functionalities of Leaflet.js was crucial to placing the characters and other map elements at fixed locations.

3.2.3.4. Web technologies

HTML, CSS, JavaScript and SVG animations were the web technologies used to implement some of the highlighted techniques highlighted in Table 2.

I. HTML5: HTML stands for Hypertext (meaning web pages can be linked via text) Markup (meaning using tags to "mark-up" plain text) Language (meaning it is a programming language) (Wempen, 2011). Furthermore, HTML5 is the most recent standard that defines the language (Mozilla, 2019b). The semantics of this language supports the creation of the structure of web pages. In this research, HTML is used to outlay the structure of the story visualization and how it will look in a web browser as prototyped in Section 3.2.2.2. All the script files, stylesheets and google web fonts are linked in the HTML documents using the *script* and *link* tags.

II. CSS3: CSS, Cascading Style Sheets, are used to manipulate and control the aesthetics and design of the HTML web page (TutorialsPoint, 2017). Furthermore, CSS3 is the latest evolution of styling web pages (Mozilla, 2019a). CSS can be implemented using either inline, external and internal styling but that done for the story visualization is external to make the project easy to manage and organize. A single CSS file was used to define the styles for the story visualization.

    Some of the story visualization metaphors achieved using CSS include:

    a) Day and night: To simulate the day and night effect in a story bubble, CSS filter properties were animated, and the opacity varied in keyframes of 0%, 25%, 50%, 75%, 85%, 100%. This was implemented in scenes 7 and 13 of the visualization.

    b) Mood and emotion: CSS colour filters were applied to the background map in multiple scenes to indicate the emotion or mood of the event being narrated.

III. JavaScript: JavaScript is the main language of the web used to create dynamic and interactive web pages (Haverbeke, 2018; Axel Rauschmayer, 2020). The scripting language can be used within an HTML document either inline, external or internal. However, external files were used to write the scripts and a few functions calls were implemented inline of some HTML tags. Several interactions and animations of the story visualization were implemented via scripting. The web mapping framework used in this research was built and modified in JavaScript as well.

    Vanilla JavaScript was used to implement the navigation of story scenes which represents the *story timeline,* as seen in Figure 3-12. The story timeline was used as a metaphor for the (approximate) temporal relationship between one event to another. For instance, the distance between the first two (2) stops on the timeline represents the approximate period between when Fan and Meng, the main characters of the story, lived at different locations before meeting each other. The wider the gap between two dots on the timeline feature, the longer the duration before the subsequent event.

    Although some story events would have occurred within seconds or minutes, in reality, the timeline gap was a bit exaggerated in consideration of the user's experience. For instance, the time between when Meng was told at the Great Wall that her husband had died to when she begins to cry would, in reality, happen in seconds. However, these two events (Meng hearing the news of the death of Fan and crying) was implemented in two scenes and putting the dots too close will make it difficult for the visualization reader to switch between scenes.

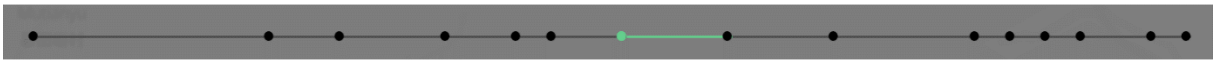


Figure 3-12. Story timeline used for navigation and as a time metaphor.

Onclick of each dot-like feature on the timeline, the corresponding scene is shown. The URL in the address bar also changes to reflect the current scene number in the format 127.0.0.1:5500/story.html#{n}; where *n* is the current scene number.

IV. SVG animations: Scalable Vector Graphics (SVGs) are not new to the field of cartography. They have been used to design digital maps, including WebGIS' (Haosheng et al., 2008; Huang et al., 2011). It is a digital technology used for visualizing complex data and concepts. The story is visualized using several vector images created and exported from Adobe Illustrator. However, to animate the images, each SVG was modified in-file using inline animation tags and attributes.

Some of the SVG animations used include:

- **clock** – in Scene 04, a metaphor for daily
- **light bulb going on and off** – in Scene 10, a metaphor for the idea
- **speech bubble** – in Scene 11, a metaphor for talking, and
- **crying with tears dropping** – in Scenes 06, Scene 08, Scene 12 and Scene 14, a metaphor for pain and sadness.
- **orange dashed lines** – in Scene 13, a metaphor for loud crying and wailing.

3.3. Conclusion

In summary, this chapter outlined the story narrative I selected to implement the story focus concept. Also included in this chapter, were the suitable techniques and technologies selected to design the cartographic representation, which was then implemented. The final cartographic product is presented in Appendix VII in the form of web screenshots. The link to the story visualization on the Internet is https://storyfocus.herokuapp.com/. It is recommended that with a minimum browser size of 1520 px (Width) × 969 px (Height) is used to view each scene. Opening the link with a browser size lower than the specified dimension will require panning to view all map elements in a scene.

4. EXPERIMENTS

The objective of this chapter is to detail how the experiment was carried out. It includes the modalities for the research methods, before, during and after the experiments. Sections 4.1, 4.2, 4.3, 0, 4.5 and 4.6 cover the research methods and justification, the research ethics, the research recruitment strategy, the equipment used, the pilot experiments and the actual experiment procedure respectively.

The effectiveness of the implemented cartographic representation compared to the text version was evaluated by involving potential users in experiments. According to Nielsen (1994), the effectiveness of any interface can be assessed *automatically*, *formally*, *informally* or *empirically*. The empirical method was selected because it involves real users, which is unlike the other approaches that are based on rules, models and formulas, or computer programs.

4.1. Research methods

The understanding and designing of appropriate research methods can lead to effective data acquisition. Qualitative and quantitative methods are the two ways through which quality data can be gathered for research purposes (see Figure 4-1). Quality research data can be gathered either using qualitative or quantitative techniques or a combination of both techniques. Combining quantitative and qualitative methods of research is possible for complementary purposes only (Sale et al., 2002). Furthermore, quality data leads to successful reviews and evaluation (Macdonald & Headlam, 2011; Allwood, 2012).

	Quantitative	**Qualitative**
Aim	The aim is to count things in an attempt to explain what is observed.	The aim is a complete, detailed description of what is observed.
Purpose	Generalisability, prediction, causal explanations	Contextualisation, interpretation, understanding perspectives
Tools	Researcher uses tools, such as surveys, to collect numerical data.	Researcher is the data gathering instrument.
Data collection	Structured	Unstructured
Output	Data is in the form of numbers and statistics.	Data is in the form of words, pictures or objects.
Sample	Usually a large number of cases representing the population of interest. Randomly selected respondents	Usually a small number of non-representative cases. Respondents selected on their experience.
Objective/ Subjective	Objective – seeks precise measurement & analysis	Subjective - individuals' interpretation of events is important
Researcher role	Researcher tends to remain objectively separated from the subject matter.	Researcher tends to become subjectively immersed in the subject matter.
Analysis	Statistical	Interpretive

Figure 4-1. Comparison table of quantitative and qualitative research methods. (Source: Macdonald & Headlam, 2011)

Quantitative research methods are mostly evaluated using statistics and mathematics such as quantitative surveys, statistical analyses and secondary data collation and analyses (Macdonald & Headlam, 2011). They expedite comparison using standard responses and deductive reasoning (Yilmaz, 2013; Han, 2018), thereby saving time and resources (Daniel, 2016). However, qualitative research methods are exploratory in nature such as questionnaires, interviews, observation, visual techniques, focus groups and workshops (Macdonald & Headlam, 2011). Unlike quantitative methods, qualitative studies give room for the participants to express themselves and their feelings in their own words through interviews and direct observations (Smeyers, 2008; Yilmaz, 2013).

Suchan & Brewer (2000) and Elzakker (2004) identified qualitative methods such as questionnaire, think-aloud, interviews and focus groups as techniques used in the evaluation of cartographic products. Due to the exploratory and descriptive nature of this research, qualitative methods were selected to capture the experience of the participants effectively. The techniques are eye-tracking, questionnaires and (audio-recorded post-experience) interview. In the sections that follow, the chosen techniques are justified.

4.1.1. Method of eye-tracking and reader observation

Eye-tracking is a research method commonly used to derive evidence-based information on the participant's cognitive activities (Lai et al., 2013). Analyzing the data from eye-tracking exercises can reveal how humans perceive and interact with visual targets (Mele & Federici, 2012). Eye-tracking is capable of answering the usability questions of interfaces such as the *order*, *location*, *time, duration,* and *frequency* users view elements on a map interface (Çöltekin et al., 2013). The technique has been used to study programming comprehension in students (Bednarik & Tukiainen, 2006), for usability studies (Li et al., 2010), advertising and marketing (Gidlöf et al., 2012), transportation (Andrew T. Duchowski, 2017), etc. A combination of eye-tracking with appropriate research techniques is capable of revealing users' thoughts based on their visual interactions with the target (Tobiipro, 2015).

Applied cartography greatly benefits from using eye-tracking to evaluate the effectiveness of created cartographic products (Alzbeta Brychtova et al., 2012; Dong et al., 2014). Therefore, eye-tracking was selected to gather information on where users look, as well as the frequency and the strategy they employed in reading the designed story visualization. The eye-tracking exercises were also used to reveal the adaptation techniques and the needs of the users in terms of the design and functionality (Popelka et al., 2012) of the representation.

Eye-tracking exercises provide a good number of metrics which can reveal users' cognitive activities. Providing answers to some of the research questions requires extracting Areas of Interest (AOIs) metrics such as revisits, gaze duration (or dwell time), fixation duration and fixation count to understand user's behaviour while reading the story visualization. These metrics are derived from two main types of eye movement behaviours recorded: fixations and saccades. Where fixations are long and steady focus on a region or object of interest while saccades are quick and rapid movements of the eyes between points of fixations (Salvucci & Goldberg, 2000; Andrychowicz-Trojanowska, 2018). The acquired metrics informed me on the pattern, count and duration users focussed their attentions on the selected regions and components of the visualization.

In a study to determine how Graphic User Interface (GUI) elements of internet maps impacts the performance and experience of users, Cybulski & Horbiński (2020) highlighted the efficacy of the eye-tracking method. The authors were able to draw insights on the decision of where to place buttons on a map interface by analyzing the participants' visual and interactive experience. Time and interaction parameters from the eye-tracking exercises were used to arrive at their findings. Similarly, I am using eye-tracking to investigate the ease with which users of the story visualization notice certain elements and if they can discover its functionality by using them.

Eye-tracking has equally been used as a method to discover how students who have geography and non-geography backgrounds read topographic maps (Dong et al., 2018). Parameters such as fixation frequency, fixation count and saccade count were the metrics used to evaluate how quickly geographers process spatial problems compared to their non-geography counterparts. The study combined eye-tracking exercises and participants' responses to the questions asked to evaluate how the two (2) categories of students processed spatial information.

In addition, Çöltekin et al. (2013) used the method of analyzing eye movements to evaluate the effectiveness of interface designs. They evaluated the usability of selected maps by employing the method of eye-tracking in terms of the complexity and advancements of interactive digital maps. Likewise, I use the method of eye-tracking to understand how users interact with the map interface and if the overall design facilitated or interfered with their ability to perform certain tasks.

In summary, eye-trackers have been used in many cognitive research fields to understand what users thoughts are like based on their visual interactions with the target stimulus (Chennamma & Yuan, 2013; Majaranta & Bulling, 2014; Bogucka & Jahnke, 2018). This research also uses eye-trackers to understand users' perception of the story visualization alongside observation to note the participant's reactions and activities not captured with the eye-tracking device. The eye-tracking device used is screen-based because the screen coordinates were needed to compute the exact places the users looked at on the story visualization (stimulus).

4.1.2. Method of questionnaires

The method of questionnaires is an easy and efficient way of ollecting certain information from participants. Easy to use in the sense that they do not require special skills by the participants and efficient because they can be used to collect quantifiable and discrete data. Collecting information on the profile (e.g. age, occupation and skill level) of the experiment's participants is rapid and systematic (Codó, 2009) using the questionnaire. Besides, questionnaire data are declarative in nature. Therefore, the risk of induced sensitive bias by the researcher is reduced.

One goal of this research was to assess how users perceive stories told with maps compared to the text version. To gather data on how the users perceive aspects of a story transferred from the text version to a cartographic representation, a series of questions needed to be asked. Therefore, a questionnaire was used. A questionnaire is a series of questions and prompts prepared by the researcher(s) to be answered by the participants (Suchan & Brewer, 2000). The data collected through the questionnaire designed for this research were both closed-ended or open-ended questions. Close-ended questions such as multiple-choice questions are straightforward and were used to get definite responses from the participants of the experiments. The closed-ended questions were also easy to encode. However, to acquire more detailed responses from the experiment's participants, open-ended questions were asked. The open-ended questions required more effort to analyze (Reja et al., 2003).

Method of questionnaires has been utilized in several cartographic studies. Standardized questionnaires have been used to collect information on user satisfaction on the use of internet maps (Çöltekin et al., 2013). For instance, questionnaires were used by Halik & Medyńska-Gulij (2017) to evaluate the experience of participants reading maps. However, Cybulski & Horbiński (2020) in their research, concluded that combining methods of questionnaire and eye-tracking was a more effective method to understand the efficiency of web map elements and the experience of its users. Hence, the method of questionnaires was adopted to evaluate, in combination with eye-tracking exercises, the effectiveness of the story visualization in telling stories. The outcome of analyzing users' responses using questionnaires delivered insights on how to effectively design cartographic representations for the story focus concept.

Specific considerations were made when designing this study's research questions. Codó (2009) recommended that the questionnaires be brief and straightforward. The questionnaire designed for this research in Appendix V was tested for clarity, brevity and ease-of-understanding by test participants (who did not participate in the actual experiment). During the pilot test, the individuals were asked about the difficulty of understanding the instructions and the average time it will take them to answer the questions was used for the main experiments.

4.1.3. Method of interviews

Interviews have been used by researchers to interact with participants. Likened to questionnaires, interviews are used to transfer opinions, feelings, behaviours and experiences from participants to researcher(s) (Suchan & Brewer, 2000; Easwaramoorthy & Zarinpoush, 2006) making it ideal for reaching the goal of this research in evaluating interviewees perception of the story visualization compared to the text version of the story. Furthermore, the method of interviews does require good listening, engaging and asking skills of the interviewer (Gill et al., 2008); hence, I conducted pilot tests to acquaint myself with the procedure.

Method of interviews is perhaps the most flexible, descriptive and in-depth technique used to get detailed information in human research but must not be seen as an informal chat session (Ryan et al., 2009; McGrath et al., 2019). To mitigate gathering redundant data or making the interview session informal, I thoroughly evaluated the questions that I needed to ask concerning the goal of this research. Another reason for this was to assess the relevance of my interview questions was to minimize the challenges that comes with analyzing the non-discrete nature of the data (Codó, 2009).

Interviews could be *structured, semi-structured or unstructured.* In structured interviews, the researcher is limited to ask only the questions that they have prepared down without further probing the response the participants give. Unlike structured interviews, unstructured interviews have little or no organization before the start of the session, and they are time-consuming. Semi-structured interviews, however, uses predetermined questions but with room to get deeper into the response of the interviewee (Gill et al., 2008; Jamshed, 2014). The popularity and effectiveness of semi-structured interviews in collecting rich information (Macdonald & Headlam, 2011; Wilson 2013) by probing the choices of the interviewees makes it ideal for this research. The semi-structured interviews for this research were conducted face-to-face.

According to Macdonald & Headlam (2011) and McGrath et al., (2019), method of interviews is a proven approach to get the subjective perceptions and opinions of interviewees on topical issues. Interviews have been used to gain further insights on a subject after the completion of questionnaires (Codó, 2009; Bullock, 2016; Quad, 2016). Therefore, the semi-structured interview approach was adopted to probe further the cognitive perceptions of the story focus concept beyond the questionnaires. However, to ensure the realization of the research goals, a back-up plan was prepared should participants decline to be audio-recorded, and this was to have the same questions answered on an extra sheet at the end of the questionnaire found in Appendix V.

4.2. Research ethics

Social and behavioural research requires that specific ethical standards be duly followed. These ethical standards, in the form of informed consent, covers the confidentiality, anonymity, privacy and safety of the research subjects. Ethical merits demand that subjects understand the research goal and procedure, consent to participate and be free to request further clarifications (Benatar, 2002; D. Smith, 2003; Rhodes, 2005; Crow et al., 2006) especially when a vulnerable population is involved.

In conducting the experiments for this research, it was essential to inform the participants about what they are about to do, how it will be carried out, and the possible consequences (Fouka & Mantzorou, 2011; Tessier & Bonnemains, 2019). Prior to the commencement of each experiment, the information sheet and consent forms created were presented to each participant. Where the information was not clear enough, an explanation was given. The participants were also informed that they could decide to stop the experiment at any time without stating their reason as well as request that their collected data be excluded from the research. They were informed of how the data collected will be processed. Because interviews are recorded and stored before they are transcribed, it was essential to get the consent of the interviewees. A copy of the information sheet and consent forms used are found in Appendix I and Appendix II. The participants, called readers, voluntarily participate in these experiments by signing the consent forms after reading the information leaflet.

Data privacy and confidentiality are essential aspects of research ethics towards ensuring the quality of a study (Petrova et al., 2016). The data collected via the eye-tracking device were labelled using identifiers that were not affiliated with the readers and discarded after the final submission of this thesis. Likewise, the questionnaire data were completely anonymized by using identifiers that are not directly linked to the readers. For the audio-recorded interviews, these were transcribed within five (5) days post-experiment exercise and discarded with no back-up wheresoever. Each reader was informed about the above privacy and confidentiality measures and consented before proceeding.

Finally, this study's research methods received the approval of the ITC's Ethics Committee at the University of Twente. This meant that the research was cleared as safe and that sufficient quality assurance procedures were put in place.

4.3. Reader recruitment

To complete the research study, that is, provide answers to the research questions, human participation was required. Readers, voluntary participants of the research experiment, were recruited through several means. One of these means was via one-on-one contact where a breakdown of the experiment tasks and goal of the research was delivered as an elevator pitch – An elevator pitch is a short and persuasive description of a concept or idea which is easy to understand by any listener (Wikipedia, 2011). Another was through referrals. People inform their connections or those within their circle about the research and its benefits. Another recruitment approach was via email. In all cases, emails were still used to confirm the reader's voluntary participation, what they need to know before participating, the location of the experiment and how to schedule a convenient appointment.

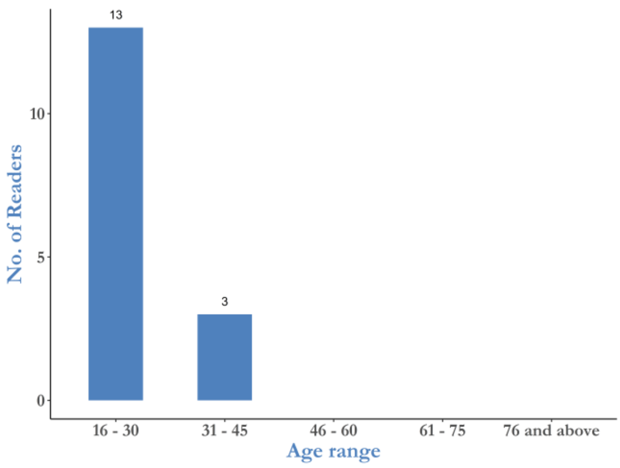
In order to efficiently manage readers schedule, a doodle premium account – with a 14-day free trial period – was created where they select a convenient day and time. Potential readers were asked to insert their valid email addresses after making a choice selection of day and time. Their emails (only visible to me), was used to communicate additional details of the experiment. A maximum of 8 slots per day for eight (8) possible experiments was designed to be selected with each having 15 minutes break in-between. The 15 minutes break was to allow for a possible longer experiment period for a previous reader and to prepare for the next in the case of a chain of experiments. Potential experiment participants were assured that their emails were not going to be visible to other participants. A copy of the experiment invitation is seen in Appendix III.

Once a reader expressed their interest and received on the scheduling application, an email was sent to confirm their registration confirmation and to give a concise overview of what will be done. Subsequently, an email is sent a day before the experiment, which included the exact location of the experiment and the time allocation selected by the reader. The recruitment began on 14 July 2020 with a registration deadline of 22 July 2020 while the experiment itself ended on 26 July 2020.

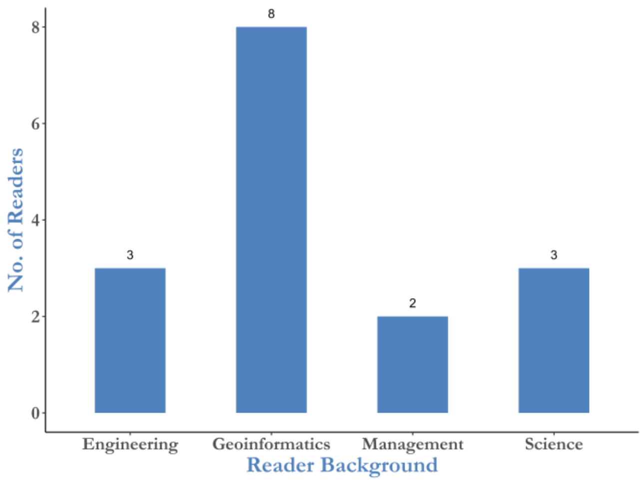
There was a pre-selection of readers. Potential readers were informed that the experiment involved the recording of eye movements using non-invasive equipment, and a few declined for reasons of existing eye disorders. In a single case, a reader could not attend their scheduled experiment because they had a cold. The latter scheduled reader incidence was mutually cancelled considering the health of the participant.

4.3.1.1. Readers profile

Sixteen (16) readers took part in the experiment. None of whom had any visual disorder. Thirteen (13) of these readers fell within the age group of 16-30 years old, while the other three (3) readers were in the 31-45 age range. Current students (6) of the University of Twente formed most of the voluntary readers, and others have jobs specifications such as Researchers, Artists, Analysts, Consultants, IT professionals and GIS professionals and were former students of the University of Twente.



(a)



(b)

Figure 4-2. Experiment readers' age group (a) and their educational background (b).

The educational background chart in Figure 4-2 (b) was aggregated based on the author's discretion for ease-of-understanding. Readers with *Engineering* as their educational background studied either Spatial or Civil Engineering; those grouped as *Geoinformatics* studied either Geoinformation & Earth Observation Science, Cartography & Geoinformatics, GIS, Geography or Geoinformatics itself.

Table 5. Profile of readers, their internet map familiarity level and knowledge of the story before the experiment.

Reader	Age group	Highest completed degree	Educational background	Occupation	Familiarity level of internet maps usage	Prior knowledge of story?
TP01	16–30	Master	GIS	Student	Very familiar	Yes
TP02	16–30	Master	Geoinformation and Earth Observation Science	GIS Researcher	Very familiar	No
TP03	16–30	Bachelor	Cartography and Geoinformatics	Spatial Artist	Very familiar	No
TP04	31–45	Master	Civil Engineering	Student	Very familiar	No
TP05	31–45	Bachelor	Urban Planning and Management	Student	Very familiar	No
TP06	16–30	Master	Geoinformatics	Geospatial Data Analyst	Very familiar	Yes
TP07	31–45	Master	Urban Planning and Management	Consultant	Very familiar	No
TP08	16–30	Bachelor	Applied Geophysics	Student	Very familiar	No
TP09	16–30	Bachelor	Computer Science	Researcher	A bit familiar	No
TP10	16–30	Master	Spatial Engineering	Student	A bit familiar	No
TP11	16–30	Bachelor	Computer Science	IT	A bit familiar	No
TP12	16–30	Master	Geoinformation and Earth Observation Science	GIS professional	Very familiar	No
TP13	16–30	Master	Geoinformatics	GIS Analyst	Very familiar	No
TP14	16–30	Master	Geography	Student	Very familiar	Yes
TP15	16–30	Master	Geoinformatics	Researcher	Very familiar	No
TP16	16–30	Master	Spatial Engineering	GIS professional	Very familiar	No

Those who studied *Management* have a background in Urban Planning & Management, and those grouped as *Science* studied either Applied Geophysics or Computer Science. Table 5 gives full detail on the background of the readers.

81.25% of the readers were "very familiar" with using maps over the internet while 18.75% were "a bit familiar". The map familiarity level was vital information to know about each reader with regards to expected interactions such as panning, zooming, clicking on the developed visualization as these are standard functionalities on most internet maps.

A potential reader could not show up due to flu a day before their experiment. Furthermore, in line with the Dutch RIVM protocols on safety regulations for the COVID-19 pandemic, were not able to participate in the experiment (Government.nl, 2020).

4.4. Equipment used in experiments

This section details the equipment used for the empirical experiments and their purpose. The equipment used is a screen-based eye-tracking system, an audio recorder and paper prints.

4.4.1. Eye-tracking System

In this section, how the eye-tracker was set-up is documented – mounting the eye-tracker on a PC, to setting it up for an experiment and calibrating the display and the eye-tracking exercise software.

4.4.1.1. Mounting the eye-tracker

The eye-tracking device used was the *Tobii Pro Fusion* from the Usability Lab of Geoinformation at ITC, University of Twente. The device can record human eye movements of a provided stimulus at a frequency of up to 250 Hz (Tobiipro, 2020b). The mobile eye-tracking device eliminated the need for participants to be present at the designated laboratory. The portable size (374 mm Length × 13.7mm Width × 18 mm Height) of the device was invaluable in the face of the COVID-19 pandemic to still perform the experiments while adhering to the health and safety guidelines.

The eye-tracking device in Appendix XI was set-up at a fixed position on a personal computer used for the experiments. For mounting the eye-tracker device on the computer, a bracket was first mounted on the bezel of the computer. The bracket was placed approximately at the centre of the bezel horizontally and held in position for about a minute. Setting up the eye-tracker device at a fixed position on the screen significantly improved the time spent for each experiment and precision of the calibration.

4.4.1.2. Display set-up and calibration

Each experiment started with the setting up of the eye-tracking device. This involved an initial calibration of the device using the free *Tobii Pro Eye Tracker Manager* software. The initial calibration with the Eye Tracker Manager increases efficiency significantly for the experiment participants before they use the *Tobii Pro Lab* software.

The Eye Tracker Manager optimized experiment time as it was used to configure the eye-tracker device on the screen. The distance between the eye-tracking device and the bezel of the computer screen itself was measured using a millimetre ruler and inputted as part of the calibration parameters. Other input parameters for the eye-tracker settings included moving the markers on the screen to align with the markings seen on the top part of the device and setting the sampling frequency to 120Hz. Thereafter, a named profile was created, and the pupil movement recorded. Figure 4-3 shows a sample calibration result for both the left eye (*orange colour*) and right eye (*cyan colour*). This procedure was repeated each time the device was removed and mounted again for an experiment session.

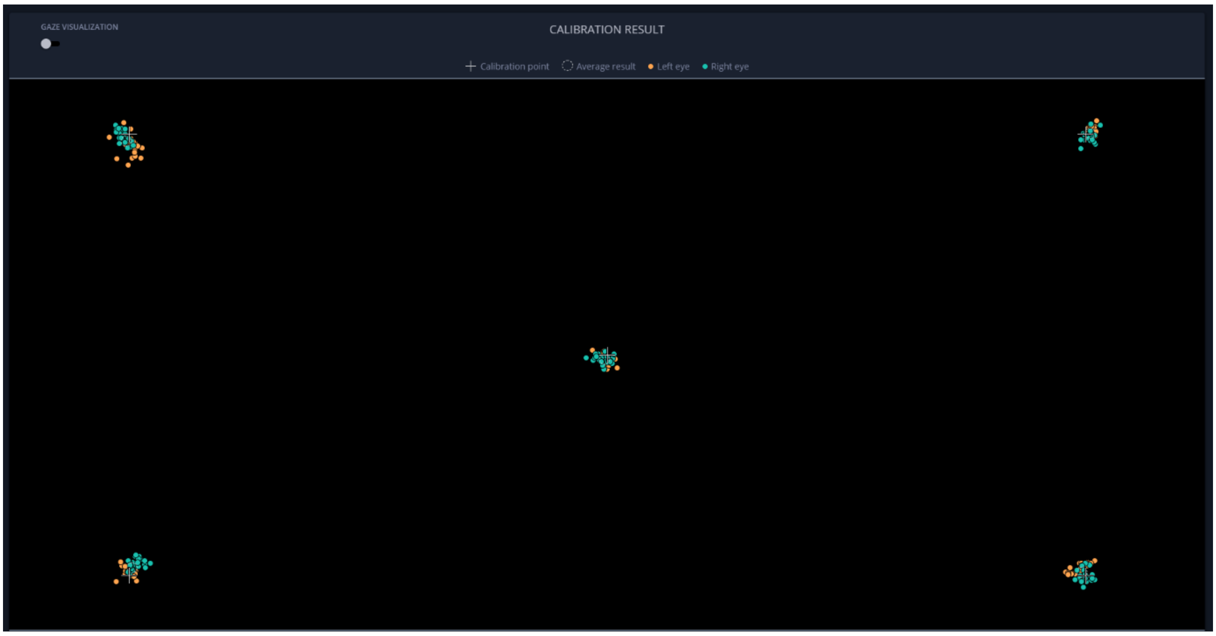


Figure 4-3. A calibration result of the eye-tracker device set-up.

4.4.1.3. Eye-tracking software

Apart from the Tobii Pro Eye Tracker Manager used to set up the display, a custom software, Tobii Pro Lab was the software tool used to manage the entire eye-tracking exercise. The software, Pro Lab, used in conjunction with the Tobii Pro Fusion device, provided a workflow for tracking, processing, and visualizing the eye movement of each reader. Additional metrics that would later be needed to understand the reader's interaction with the story visualization created were provided on the software to be exported as CSV. Appendix XI shows both the minimum system requirements specification versus that of the computer system utilized.

Pro Lab manages the eye-tracking exercise in five-tab steps: Project, Design, Record, Overview, and Analyze tabs. A named project was created for this research in the "Tobii Pro Lab" project tab. The experiment was designed in the "Design" tab by setting up a timeline. The timeline used a web stimulus which was the URL to the story visualization developed. In the design tab, the presentation setting was set to the computer's display resolution of 1920 × 1080. On the "Record" tab menu, the Eye Tracker is selected, and an identifier to serve as the participant's name and recording name was inputted. An overview of the project after recording is on the "Project Overview". The project overview tab highlights each recording's duration, system date and time, participant names and recording names, gaze sample (in percentage), and validation accuracy and precision. The fifth tab, "Analyze" contained post-processing functionalities like *Visualization, AOI tool, Metrics* and *Data Export*. The result analyses were exported as images and spreadsheets. After each day's experiment, a backup was manually created.

Noteworthy, the computer used, had a lower CPU and RAM capability. The effect is the significant loss of frames (about 8%) which caused gaps in the gaze video replay; however, the gaze and video data synchronization was intact. Situations where there was a loss of frames (a single scenario), the reader voluntarily agreed to repeat the exercise.

4.4.2. Audio recorder

The audio recorder used for the study was the default voice recorder on a person mobile phone – Samsung Galaxy J4 2018. A dedicated memory card with a 32 Gigabyte capacity was used for the sole purpose of the study. A real-time back up of each audio recording was set up to prevent data loss.

Prior to the start of each experiment, the readers were sufficiently informed that they would be recorded, and they consented on the form in Appendix II. Consent, privacy and confidentiality were enforced as elaborated in Section 4.2.

4.4.3. Questionnaire

Both open-ended and closed-ended questions were constructed to explore the profile of the reader, and their experience reading both the story visualization and the text version. The questionnaire (Appendix V) was printed in A4 sheets and administered to each participant. Then the questionnaire data were transcribed into digital documents for further processing and analysis.

The closed questions required the readers to select only one option provided or, in some cases, as many as they considered right while leaving room for other options that were not specified. The open-ended questions were mostly used to get the readers to describe their feelings and experience of the completed task.

4.5. Pilot experiments

Rothgeb (2008) referred to pilot tests as "dress rehearsals" because they help to identify potential problems before the main exercise quickly. Two pilot experiments were conducted by random students of the University of Twente as if it were the main experiment. The tests were successful in estimating how much time each experiment schedule would take and in the optimization of the main experiment workflow. The participants of the pilot tests did not take part in the experiment outcomes reported in this research and had their data deleted before exiting the test location.

The pilot experiments optimized the workflow of two of the selected research methods the most: the eye-tracking exercise and the interviews. For the eye-tracking exercise, the test session helped identify the need to restart the computer used before each session for improved system performance. Also, during the pilot test, it was observed that Tobii Pro Lab's built-in browser, which served the web stimulus, rendered the URL rather slowly causing a delay in reading the story visualization. The workaround was to run a sample test prior before the time scheduled for an experiment. Furthermore, Tobii Pro Lab records interaction with web stimulus and maps the gaze data to a snapshot per unique URL. However, the story visualization, which was designed as a SPA, had no hooks to uniquely identify the navigation to another scene with a URL in the browser's address bar. The mapped gaze data was aggregated only on the last story scene. Hence, the story visualization was modified, as shown in Section 3.2.3.4 to include a unique URL for each scene. Some questions in the interviews were recognized to be redundant to the objectives of the research and were removed.

Overall, the pilot tests accomplished the goal of pruning and optimizing the experiment workflow. Approximately ten (10) minutes was saved after the completion of the trials, bringing the total scheduled time for the experiment to 35 minutes.

4.6. Execution of the research experiments

The experiment was conducted in three stages (as summarized in Figure 4-4) with English as the language of communication. Tracking human behaviour and eye movement with the eye-tracking device while reading the story visualization was the first stage. Then the reading of the text version of the story. Lastly, a post-experience interview to get an in-depth understanding of readers' feeling, opinion and experience. The consent form was signed before the start of the tasks.

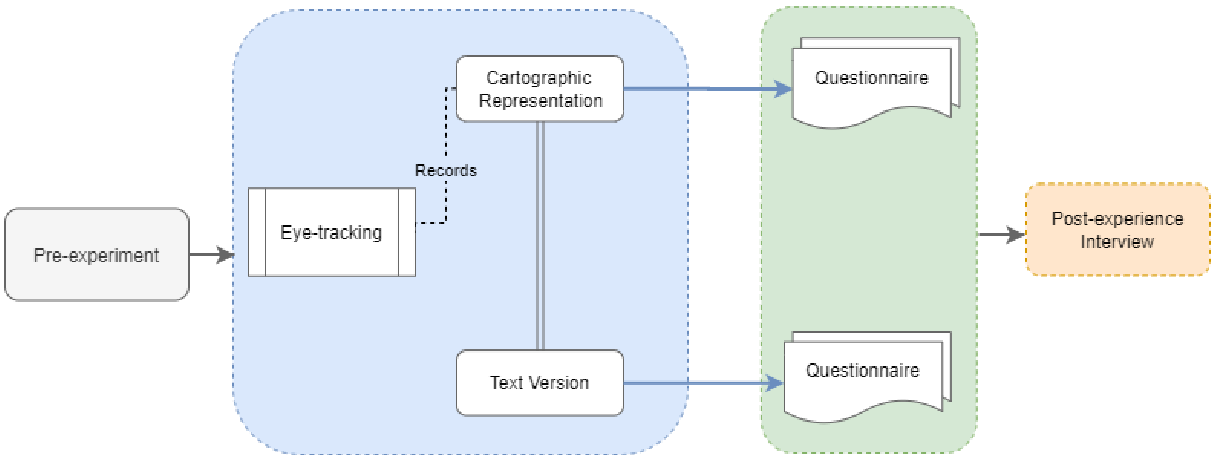


Figure 4-4. Workflow of the research experiment.

The main experiment began with the method of eye-tracking. In the project tab of the Tobii Pro Lab software, a directory was created where the eye-tracking data of each reader was saved. On the Design tab, the experiment's timeline was designed to include only a web stimulus. The web stimulus was a URL object of the story visualization served over localhost on a computer (see Appendix XI for specifications of the computer used). The recording tab is the next step where a unique identifier unlinked to the personal information of the reader was inputted as the "participant name" as well as the recording ID. At this point, the reader is re-informed that they will be calibrating and validating their gaze once the recording starts and would need to maintain their chosen sitting position until the completion of the recording. The recording starts with the click of the record button. Shortly afterwards, the reader was prompted by the software to calibrate and validate their gaze by using their eyes to follow targets displayed on different parts of the screen. A minimum gaze sample of 90% was set for each reader before they could proceed. The story visualization opened in a web browser, and the reader interacts with it. The escape (ESC) button on the computer's keyboard was clicked to terminate the gaze recording. While the readers were using the eye-tracker, their activities and reactions were observed. Readers were given the opportunity to watch the replay of their gaze recording, should they wish to do so.

Next, the reader completes the questionnaire part on the story visualization. Firstly, the reader was asked to write the story they perceived from the story visualization they just read. The goal was to evaluate the memorability and understanding of the story being narrated with the visualization. For the part of the questionnaire where the readers needed to describe the emotions, they revisited the visualization. Completing this part of the questionnaire required the reader to match each scene with its emotions, if present, and their corresponding identifiers.

Upon completing the eye-tracking exercise and questionnaire of the story visualization were completed, the text version of the story is presented to the participant to read. The reader reads the text version of the story, and their reactions were observed. The reader then completed a corresponding questionnaire for this stage of the experiment.

In the final stage – the post-experience interview, the readers were asked about their experience and opinions. The first question was to identify what medium conveyed the story better and what aspects of the story influenced their choice. The other question was to receive feedback on the story visualization. Additional probes were used to understand the reader's choice for each interview question. However, during the pilot phase, one of the test readers declined to be audio-recorded, and this prompted the need to include the verbal questions as a supplement to the questionnaire.

Daily backup of the entire project was done using the export project functionality to forestall the loss of data. A checklist for the research experiment can be found in Appendix IV.

4.7. Processing of eye movement data

The data collected from recording the eye movement of the readers were processed as heat maps and gaze plots for qualitative interpretation and Areas of Interest (AOI) metrics for quantitative analysis.

4.7.1. Heat maps

A heat map, also known as a *fixation density* map, is one of the visualization techniques this research uses to assess where the readers' gaze was the least or most fixated on the stimulus displayed on a screen. In generating the heat maps, the Tobii I-VT (Velocity-Threshold Identification) Fixation filter was used. The filter works by classifying the reader's eye movements based on the eye directional shifts velocity (Olsen, 2012). Appendix XII gives a complete breakdown of the filter configuration used.

The basis upon which the heat maps was created is the "Absolute count", computed from the number of fixations by the software. The absolute count basis was selected to get an understanding of how many times the readers had their gazes fixated on different portions of the stimulus. Additional calculation basis included in the software includes absolute duration (which works by computing the period of fixations), relative count (calculated for a Time of Interest (TOI), the number of fixations made by a reader relative to the total number of fixations), and relative duration (which computes for a Time of Interest (TOI), the number of fixations by a reader relative to the total number of fixations on the mapped screenshot) (Tobiipro, 2020b). The calculation basis explained here is referred to as "Type" on the software dashboard as a dropdown option.

Other custom settings made on the software to generate the heat maps for its appearance were:

i. Background image: The snapshots captured during the recording of each unique URL was used as the background to give a visual understanding of where the readers had their gazes fixated.

ii. Colour: The colours to represent the levels of data, low, middle and high are Green – #00FF00, Yellow – #FFFF00 and Red – #FF0000, respectively. The colour scheme used is original to visual depictions of clusters (Wilkinson & Friendly, 2009).

iii. Opacity: The opacity level was set to 100% to ensure the best transparency of the heat map with minimum distractions.

4.7.2. Gaze plots

A gaze plot, also referred to as scan paths (Olsen et al., 2010), shows the path of the readers' eyes over the recording period on the stimulus. The gaze plots were used to gain hints on the readers' thoughts and intents (Majaranta & Bulling, 2014). The configuration for the gaze plot filter used is the same as that used in the heat map filter, as seen in Appendix XII.

Similar to the custom settings for the heat map's appearance, those of the gaze plot are:

i. Background image: The snapshots captured during the recording of each unique URL was used as the background to give a visual understanding of where the readers had their gazes fixated.

ii. Scale: A coverage size of 20px was applied to ensure sufficient visibility of all fixation circles.

iii. Border colour: The colour white (#FFFFFF) was used to emphasize the circle boundaries.

iv. Fill colour: For this research, random colours were generated and assigned to the fixation circles for each recording to give a visual clue of all the readers' cognitive activities.

v. Saccades: The connections between fixation circles as readers look at different parts of the stimuli were equally applied to show the connections.

vi. Opacity: The opacity level was set to 80% to ensure the best transparency of the gaze plot with minimum distractions while allowing for the visibility of overlapping fixation circles.

4.7.3. Areas of Interests extraction

Areas of Interest (AOI) is a technique used to acquire numerical and statistical analysis of features and regions that are of interest in this study. The technique enabled quantitative analysis by calculating the movement of the eyes, such as counts and durations of fixations. On the Tobii Pro Lab software, closed geometries were created around elements and regions of interest for each unique URL of the web stimuli. The AOIs drawn were of varying shapes, sizes and locations.

Selecting AOIs is a common problem in eye-tracking research (Hessels et al., 2016). In designing and analysing the AOIs for this research, it was important to consider the size and placement of the AOIs as well as negotiating selectivity and sensitivity. That is, the amount of gaze data to be utilized in the AOI computation. The smaller the AOI, the higher the selectivity needed thereby eliminating irrelevant gaze but with a chance of losing a valid gaze. However, larger AOIs mean higher sensitivity and a greater potential of capturing the true gaze but the inclusion of irrelevant gaze (Tobiipro, 2020a).

In the case of selecting multiple AOIs, it was important to consider the proximity of AOIs to one another. According to Tobiipro (2020), AOI placement influences the computational accuracy and relevance of the gaze metrics. Similarly, the spacing between AOIs equally impacts the balance in selectivity and specificity. Therefore, in processing the eye movement data, the AOIs proximity was carefully considered.

Figure 4-5. Sample AOIs selected for a story scene. shows a sample scene snapshot with its designed AOIs and those for all other scenes can be found in Appendix VIII.

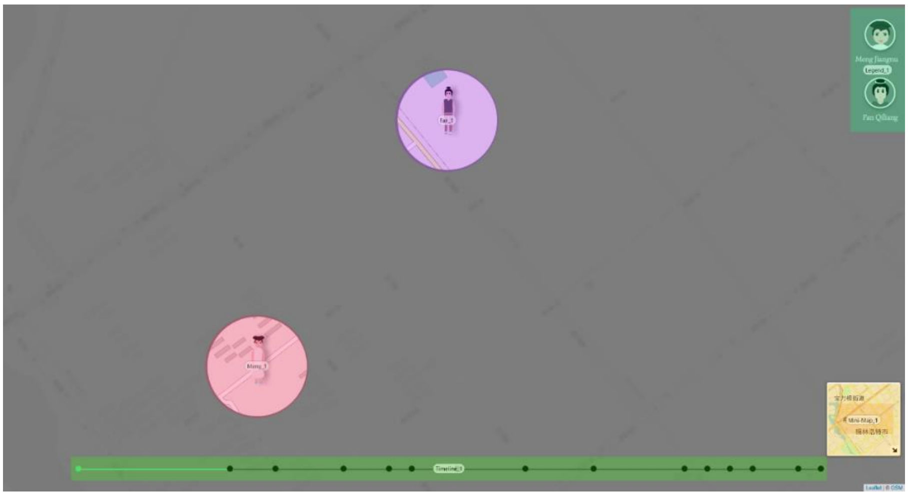


Figure 4-5. Sample AOIs selected for a story scene.

The following metrics were extracted from the selected AOIs:

i. Total duration of fixation in AOI: The sum duration a reader fixated on designed AOIs. This metric was used to investigate how much time readers were fixated on each scene's story bubble, legend and mini-map.

ii. Time to the first fixation in AOI: Time in seconds taken before the eyes are fixated on an AOI. Determination of what feature of the visualization was first reached by the readers when reading each story scene was derived using this metric. Similarly, readers cognitive behaviour for the button to repeat animation was evaluated for discoverability using the time to first fixation metric.

iii. Time from the first fixation to click in AOI: Time in seconds from when a reader's eyes are fixated on an AOI to the time they click in the AOI. The repeat animation button was evaluated for the time it took readers of the story visualization to discover the feature and then its functionality by clicking.

iv. The total duration of visit in AOI: The sum duration a reader visits each AOI. This metric was useful in evaluating the time spent: by each reader per scene of the story visualization, on each scene's legend, on each scene's mini-map, and the story bubble(s) per scene.

4.8. Conclusion

The current chapter outlined the research methods and procedures. It also detailed who the readers were and how they were recruited for the experiment. In Chapter 5, the results from the eye-tracking, questionnaire and interview exercises will be presented and discussed.

5. RESULTS AND DISCUSSION

The outcomes of the reader experiments are presented in this chapter of the research. The results presented in this chapter are outcomes of the research's methods of eye-tracking exercises, questionnaire responses and post-experience interviews. At the latter part of this chapter, both the quantitative and qualitative analyses are combined to derive insights.

Prior to the start of analyzing the readers' data, a backup copy was created for safekeeping. Backup of the readers' questionnaire responses, interviews and eye-tracking exercises were transcribed, anonymized and stored in Word and Spreadsheet documents. After the analyses were completed, all copies of the data were destroyed with no backup wheresoever.

5.1. Analysis of eye movement data

In analysing the cognitive traits of the readers, several variables were extracted, visualized and analyzed. In the sections that follow, the data extracted from the readers' exercises are explored to gain valuable insights.

5.1.1. Heat Maps

The heat maps were generated for each unique snapshot of the stimuli, which were automatically captured during the eye-tracking exercise. Each heat map found in Figure 5-1, Figure 5-2, Figure 5-3 and Figure 5-4 is an aggregation of the observation intensity by all the readers per scene. The colours represent the fixation counts for all readers. A greater number of fixations is represented with a warm colour (red), and fewer fixation counts with a cool colour (green).

An overview of the fixation distribution on each story scene shows that readers were more fixated in the story bubbles and less fixated in the greyed-out areas of the maps. However, when aspects of the story were implemented in the greyed-out area of the map, fixation counts were recorded. For example, where the metaphors for the long part of the Great Wall and the crying aloud of Meng Jiangnu were implemented in the greyed-out part of the map, readers also fixated on these areas of the map.

Other components of the story visualization also recorded fixations. A pattern of viewing intensity was observed for the legend. Readers viewed the legend more in the first scene compared to the following scenes and only increased intensity when a new item is added. For instance, the heat maps show that readers looked intensely at the legend in Scene 01 which has the two main characters of the story and looked less intensely in Scenes 02 and 03 where the legend content remained the same. However, when a third character, the government forces, was added to the legend in Scene 04, the readers looking intensity increased again. Similarly, when a new item, the bones of Fan Qiliang was added to the legend, readers looked more at the legend compared to previous scenes legends where the content was the same.

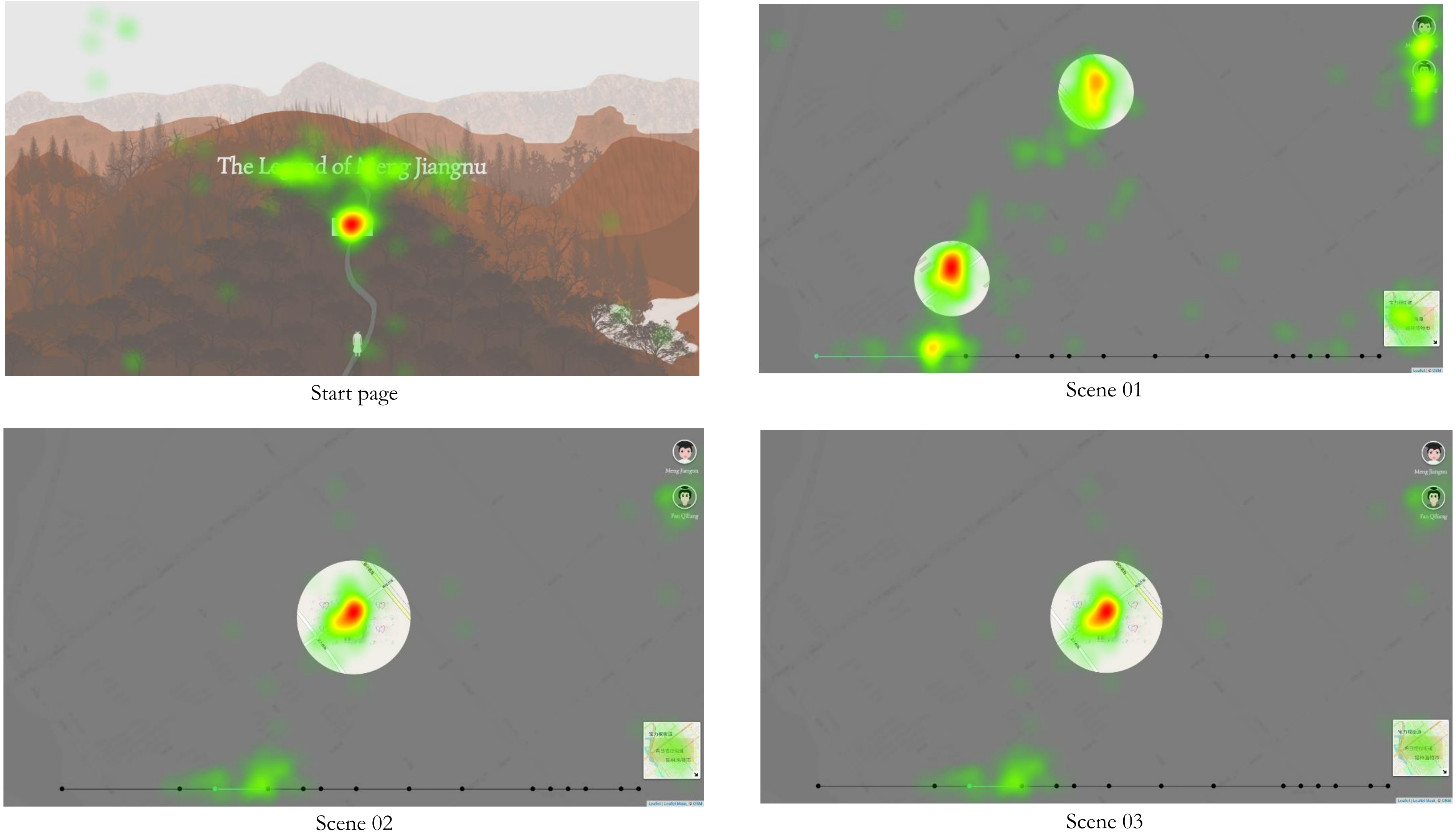
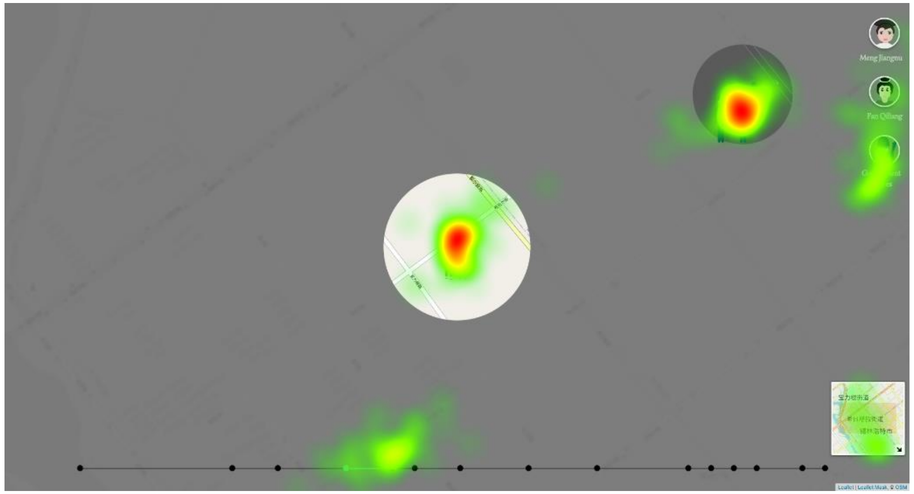
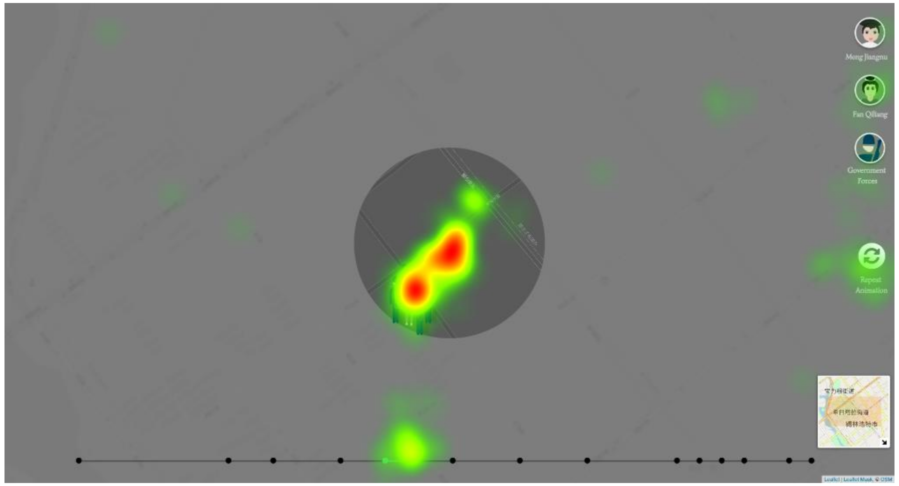


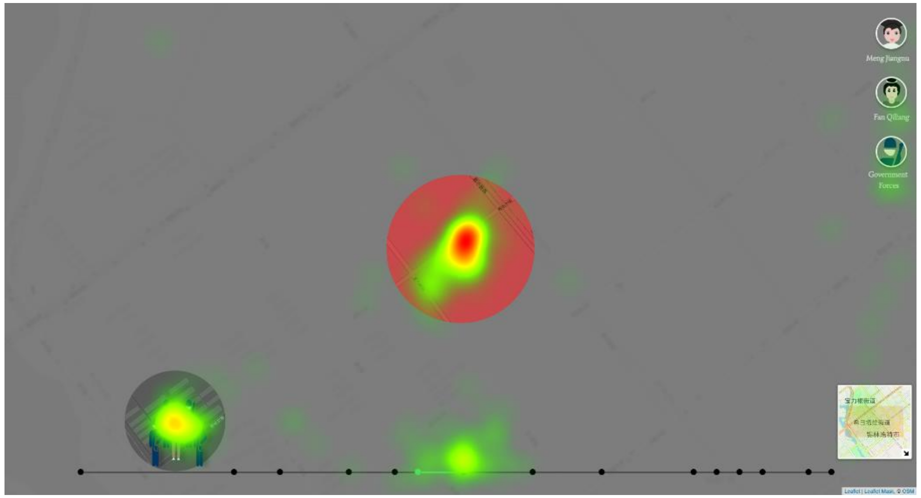
Figure 5-1. All readers heat map of the start page, Scene 01, Scene 02 and Scene 03.



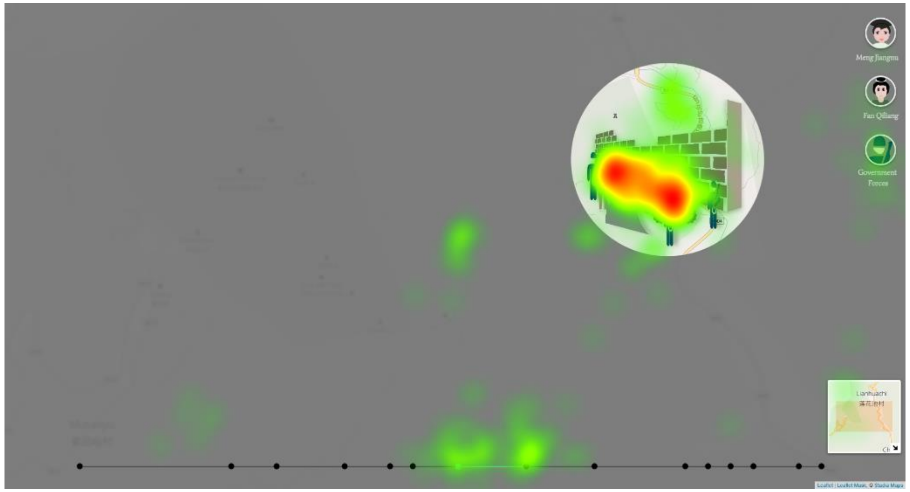
Scene 04



Scene 05

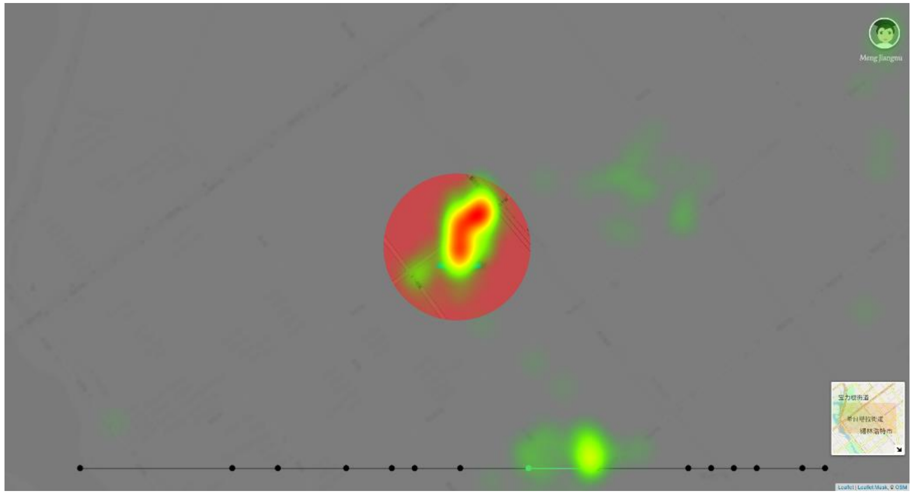


Scene 06

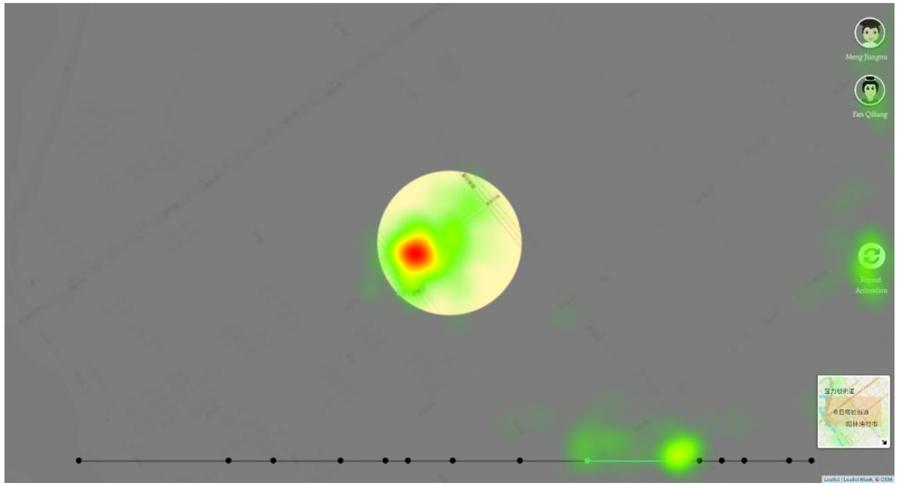


Scene 07

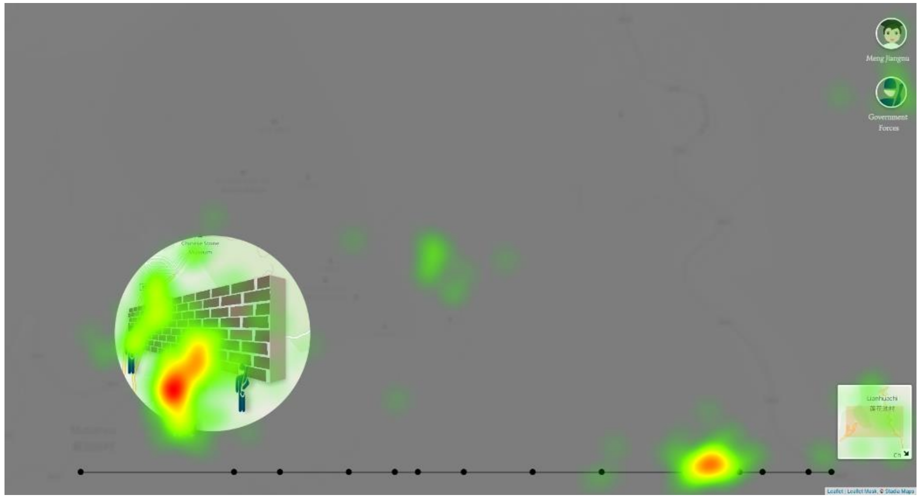
Figure 5-2. All readers heat map of Scene 04, Scene 05, Scene 06, and Scene 07.



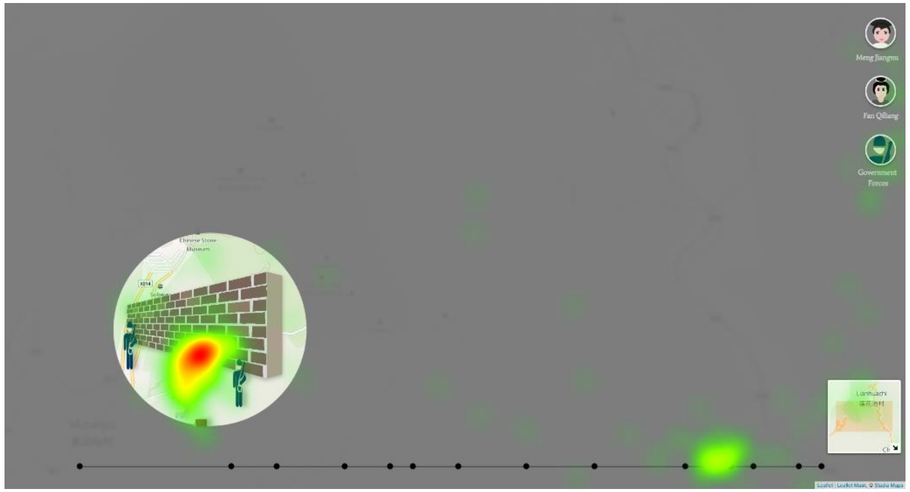
Scene 08



Scene 09

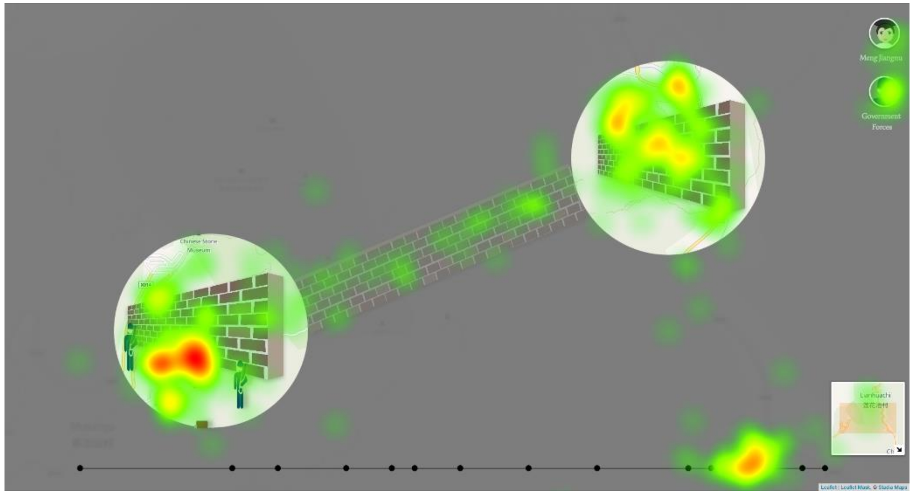


Scene 10

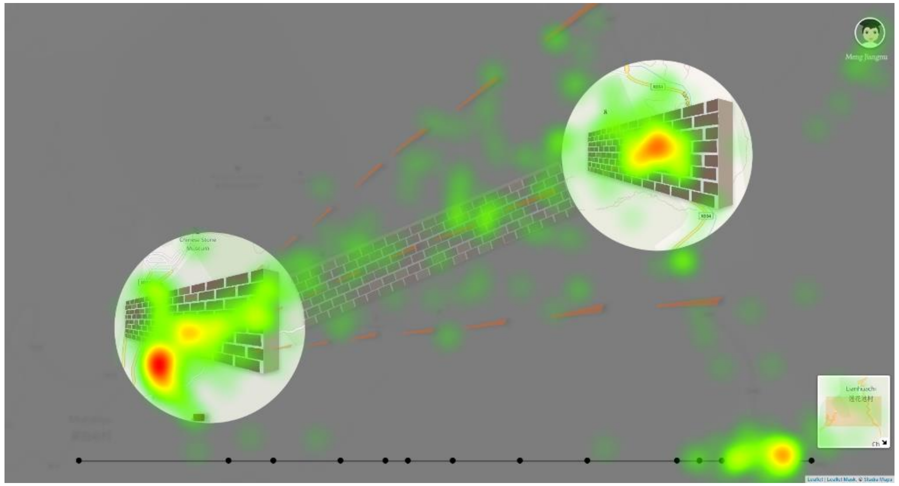


Scene 11

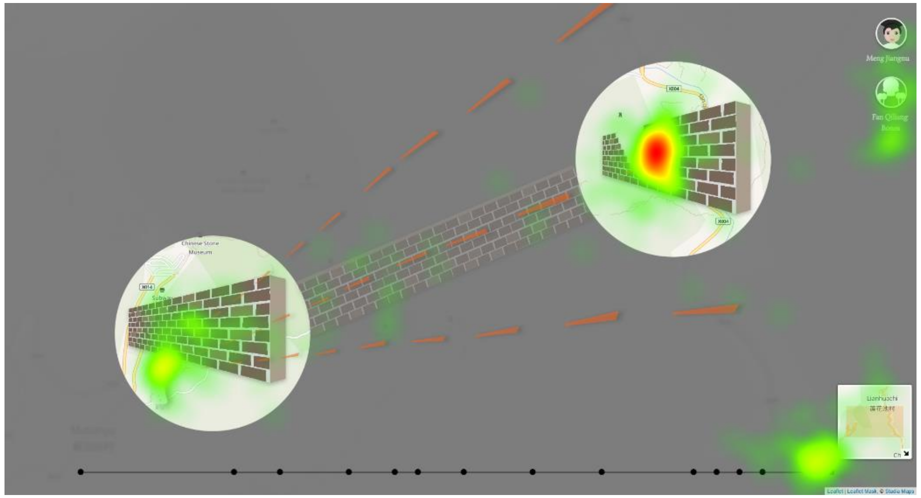
Figure 5-3. All readers heat map of Scene 08, Scene 09, Scene 10, and Scene 11.



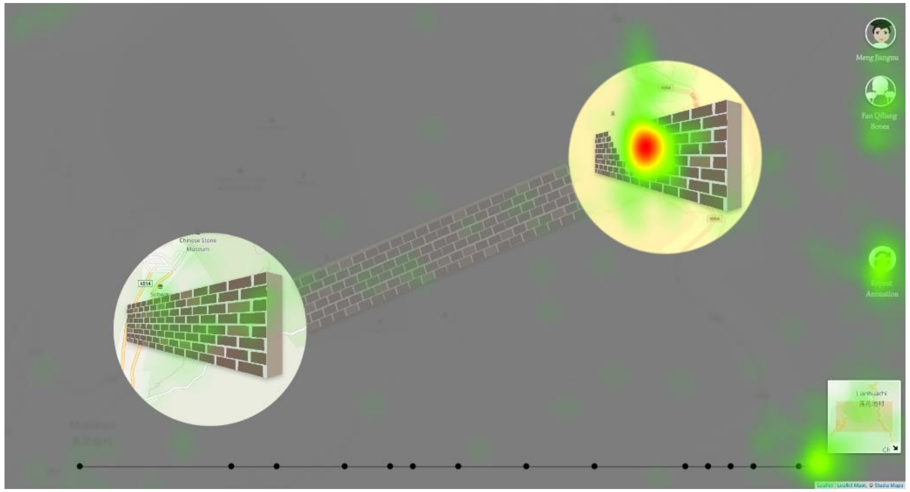
Scene 12



Scene 13



Scene 14



Scene 15

Figure 5-4. All readers heat map of Scene 12, Scene 13, Scene 14, and Scene 15.

The mini-map reading intensity had a noticeable pattern also. Readers start the story visualization reading in Scene 01 looking at the mini-map attentively, but the intensity reduces as they proceed to read other scenes. Although the second map tile and location was introduced in Scene 07 and then in Scene 10 to 15, readers did not give increased attention to the mini-map but instead varied randomly.

The timeline, which served dual purposes for the story visualization, recorded users' attention to it. Serving both the purpose of approximate time between events and the visualization navigation, readers focused a lot on the timeline feature in Scene 01 but steadily declined their intensity in the two (2) scenes that follow. The readers soon increase their fixation count from Scene 04 with higher intensity in Scene 10. A sudden reduction in fixation occurred in Scene 11 before readers continued with the same high intensity as in Scene 10. A gradual drop in fixation count by the readers was also recorded from Scene 14 to Scene 15.

The repeat animation buttons also had fixation counts recorded by the readers. The animation button was implemented in Scene 05, Scene 09 and Scene 15 and had a progressive increase in the number of fixations. The density of the readers' fixation was few in Scene 05 but increased in Scene 09 and the most in Scene 15.

Although readers hardly fixated their gaze on the greyed-out areas of the visualization, there were exceptions. An instance where readers looked outside of the story bubbles was the crying aloud animation of Meng Jiangnu at the Great Wall, which originates from a story bubble and spreads to the greyed-out area. Despite that, only a small fraction of gaze data was found in these areas.

In summary, the heat maps gave insights into the possible regions of the story visualization looked at. For some components, the number of fixations was constant while in others, they varied from scene-to-scene or randomly.

5.1.1.1. Gaze plot

The gaze plots, used for scan path analysis of this research, were generated for each unique snapshot which were automatically captured during the eye-tracking exercise. Each gaze plot found in Appendix IX is an aggregation of all sixteen (16) readers who participated in the experiments. The gaze plots depict the looking order, location and duration (directly proportional to the radius of a circle) of readers on the story visualization. In order words, the gaze plots reveal the readers looking sequence, the where and the when they look at the web stimulus.

Each circle, called the fixation circle, has a number at the centre. The number indicates the *n*th time a reader looks at a web snapshot (Figure 5-5). Unique colours were randomly assigned to each reader's fixation and saccades.

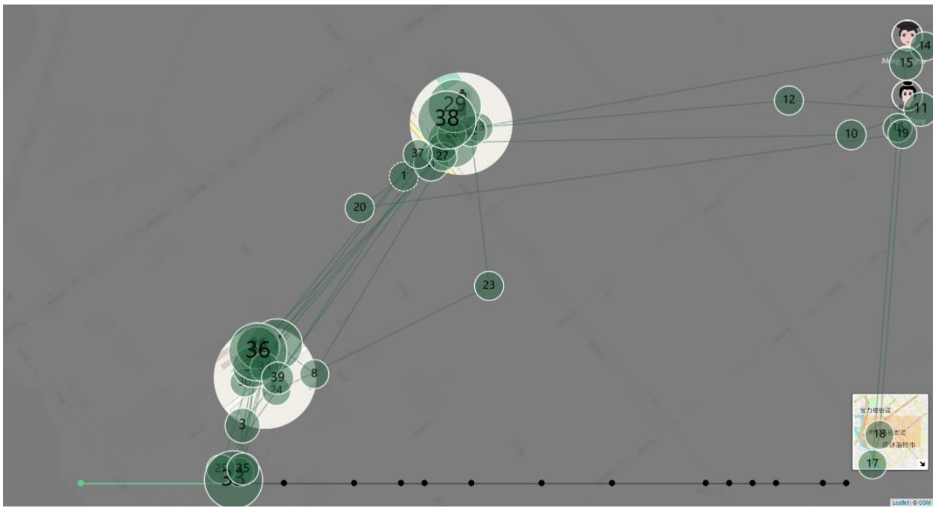


Figure 5-5. Sample gaze plot of a reader for a story scene.

A consistent pattern was observed in the looking order, place and duration of all the readers. Figure 5-5 shows the chain of gazes of a reader. The selected reader began reading from the story bubble above, then fixated on the second bubble before moving to the legend. After the legend, the reader fixated on the mini-map and then the timeline. The described pattern was the same for all other readers. Also, when a story scene with a repeat animation button was presented to the reader, the reader looked there last. In addition, readers focused more on the story bubbles as indicated by the fixation circles sizes and counts.

5.1.1.2. Areas of Interest (AOIs)

Processing of information by the readers took place during fixation and visit durations. Therefore, to perform quantitative analyses of the readers' cognitive behaviour, the extracted metrics are presented in the sections that follow.

I. Reader's reading time

The mean total time taken to complete reading the story visualization was 300secs with 157secs and 487secs as the minimum and maximum duration, respectively. These reading times excludes time used by the readers to calibrate and validate their gaze at the start of the eye-tracking exercise.

The distribution of time taken by readers of the story visualization is presented in Figure 5-6. For example, reader *TP01* spent a minimum 10.71secs and a maximum 23.78secs but a mean time of 15.87secs reading a scene of the visualization. Some readers had scene reading times that were numerically distant from their other scenes reading times (i.e. outliers) represented as dots. Reader *TP04*, for example, had two (2) outliers with recording times of 20.10secs and 20.35secs reading scenes 02 and 04, respectively. Reader *TP05* also had two (2) outliers of 18.65secs and 37.66secs reading scenes 01 and 15, respectively. *TP06* had their outlier data reading scene 01 with a duration of 35.77secs. However, *TP14* having an outlier of no recording time at Scene 02 indicates that they possibly skipped reading that scene.

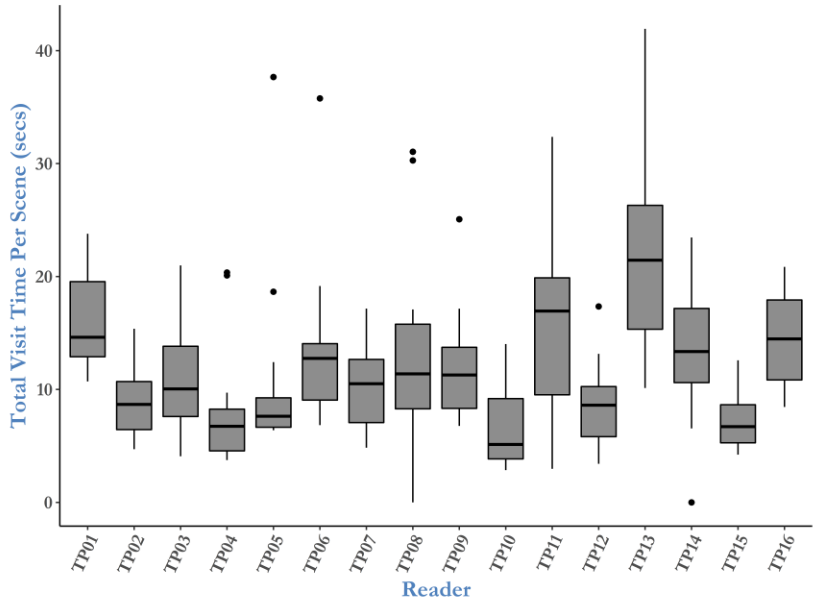


Figure 5-6. Distribution of visit duration by readers on each scene.

Reader *TP13*, from the gaze fixation data, spent the most time reading each scene with a maximum of 41.93secs on Scene 13. The least time *TP13* spent, 10.13secs, was spent reading Scene 10 of the visualization. However, the median and mean time *TP13* spent reading a scene stood at 21.45secs and 22.27secs, respectively. Conversely, *TP10* spent the least time reading each scene of the visualization with a mean time of 6.64secs and a median of 5.13secs. The minimum time spent by *TP10* was 2.86secs in reading scene 04 while they spent 14.02secs reading Scene 14. Compared to all other readers, *TP16* had a well-spread time distribution reading the story scenes. *TP16* spent an average of 14.39secs, and a minimum and maximum time of 8.45secs and 20.85secs, respectively. The minimum reading time was spent on Scene 01, while the maximum reading time was spent reading Scene 06.

II. Reading the scenes

The distribution of time readers spent reading each scene of the story visualization is presented in Figure 5-7. Scenes 15 was where readers spent more time reading the story visualization. The median total time spent reading scene 15 was 15.68secs which was the highest compared to other scenes. In contrast, Scene 03 had the least median time of 8.51secs.

Several outliers visit times were observed in the recordings of the readers. The highest outlier was in Scene 11 at 41.93secs by reader TP13. Other scenes with recording times that were distant from the others where Scenes 01, 04, 09, 10, 11, 13, 14 and 15. In six out of the eight scenes with outlier data, TP13 was the reader who also completed reading the story visualization in 487secs, the highest.

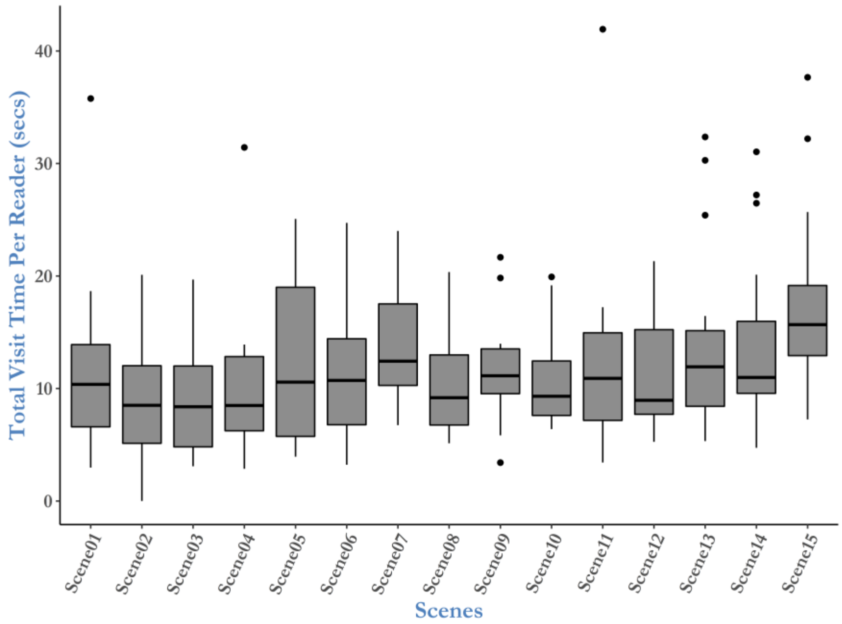


Figure 5-7. Distribution of visit time by all readers on each scene.

Finally, Scene 02 had a recording value of 0.00secs by a reader. An explanation for this might be that the reader skipped reading this scene.

III. Reading of the legends

An essential element of most maps, both static and interactive, is the legend. A legend unlocks the meaning to map features. The legends in the story visualization provided the extra information on the symbolized characters. To understand how users adapted to the technique of varying legend content used in the story visualization, the mean total time readers fixated on each scene's legend was calculated.

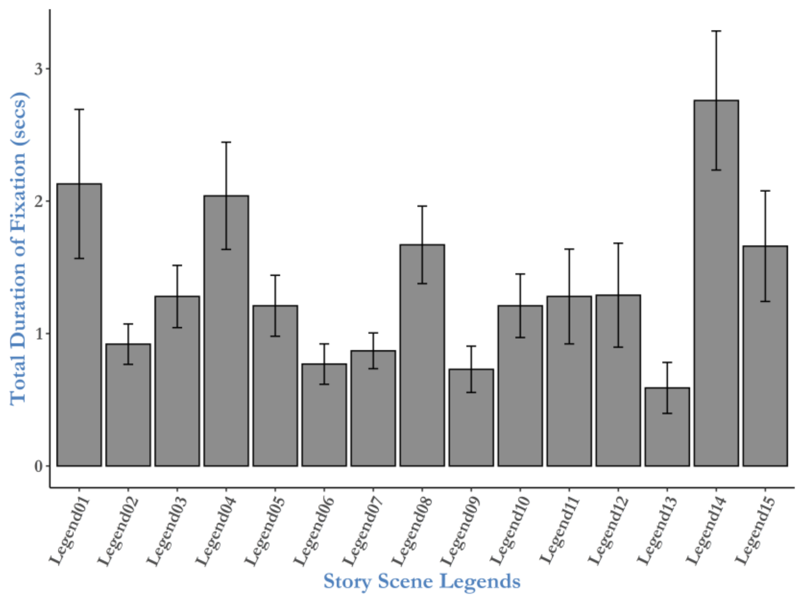


Figure 5-8. Mean of the total duration of fixation on each story scene's legend.

Figure 5-8 shows that readers spend readers spent an average of 2.13secs viewing the legend on Scene 1 (Legend01) but soon spend lesser time only to increase time spent when an item they have not seen prior is introduced. The next significant increase in fixation duration Legend14 compared to others. The error bars indicated on each bin of the graph in Figure 5-8 represent the deviation from the mean to account for all readers, i.e. +/-.

Table 6. Percentage average duration readers fixated on the legends.

Story Scene Legends	Share of Total Time (%)
Legend01	20.72
Legend02	9.53
Legend03	4.9
Legend04	16.03
Legend05	4.16
Legend06	4.38
Legend07	2.56
Legend08	4.11
Legend09	4.12
Legend10	2.81
Legend11	5.47
Legend12	4.69
Legend13	1.42
Legend14	9.94
Legend15	9.87

Readers of the story visualization fixated their gaze on each scene's legend at varying proportions, as presented in Table 6. On average, readers fixated their gaze a lot more on the legends in scenes 01 and 06, where they both have above 15% reading time. Scene 1 is the start of the story, and readers are seeing the characters of the story for the first time. Spending an average of 20.72% of Scene 1's reading time suggests that they could be trying to memorize the names of the characters. Afterwards, the proportion of time spent by the readers on the legends on scenes 02 and 03 was halved.

However, in Scene 04, a new character was added, and the readers increased the time spent interpreting the new character from the legend. The percentage duration, 16.03%, was four times that of the previous scene (i.e. Scene 3). The fixation on the legend in nine (9) scenes that followed varied between 1.42% and 5.47% of the average scene time.

A new character, Fan Qiliang's bones, was first added to the story visualization in Scene 14. The percentage duration of fixation on the visualization's legend went from a previous scene's mean of 1.42% to 9.94% in Scene 14. However, unlike previous scenarios where the percentage fixation time of the scene drops by at least half, Scene 15, had a similar percentage fixation time of 9.87%.

IV. Reading of the mini-maps

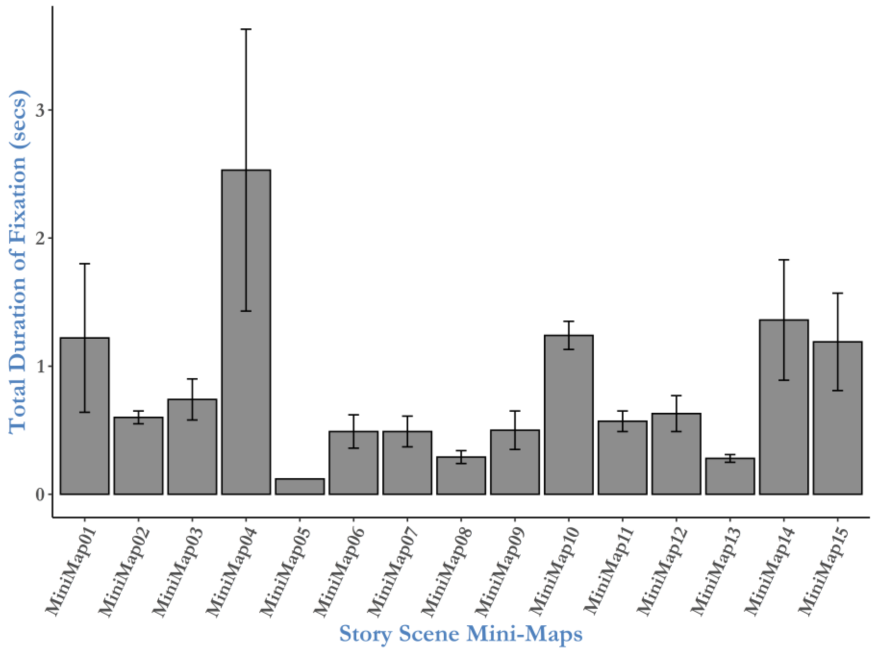


Figure 5-9. Mean of the total duration of fixation on each scene's mini-map.

One of the visual clues to aid story place identification was mini-maps. It was possible to provide additional context to the story's location in the real world using zoomed out levels on the map. Readers found this as a useful hint to answer the question of *where* of the narrated story. Maps tiles, locations and zoom levels were varied, leading to different views in the mini-map scene-by-scene. Observably, Figure 5-9 shows how the cognitive interaction of the readers with the mini-map change. It can be inferred that readers were the most curious of the story location via the mini-map in scene 4 of the visualization. The fixation duration used is the average value aggregated for all readers with the deviation from the mean, represented as error bars, to mean +/- the mean duration.

Table 7. Percentage average duration readers fixated on the mini-maps.

Total duration of Visit	Share of Total Time (%)
MiniMap01	12.91
MiniMap02	2.84
MiniMap03	4.23
MiniMap04	9.93
MiniMap05	0.08
MiniMap06	2.10
MiniMap07	1.16
MiniMap08	0.72
MiniMap09	1.76
MiniMap10	4.81
MiniMap11	2.45
MiniMap12	1.83
MiniMap13	1.19
MiniMap14	4.08

MiniMap15	6.51

The readers' visual pattern in reading the mini-maps varied widely. Using all the readers average visit times, more time was spent on the mini-map in Scene 01 where the percentage reading time was 12.91% out of the total visit time on the scene. In Scene 04, readers visited the mini-map 9.93% of the total time in the scene. Close to the visit duration of Scene 04, readers spent 6.51% of the visit time reading the mini-map in Scene 15. In other scenes, the percentage visit duration on the mini-map was less than 5% indicating more focus on other components of the visualization in those scenes.

V. The story buttons

The story visualization had buttons to repeat the movement of characters in space at intervals. These buttons were available on scenes 05, 09 and 15. Out of the 16 readers who partook in the experiment, 5, 6 and 8 readers identified (time to the first fixation) and understood the functionality of (i.e. clicked) these buttons in scenes 05, 09 and 15, respectively. Although not more than 50% of the readers noticed and used the repeat animation button, Table 8 shows readers were only aware towards the end of the story and that the time between when they identified the button to when they used it only increased as they progressed.

Table 8. Time from the first fixation to click of *repeat animation* button.

Time from first fixation to click	Scene 5	Scene 9	Scene 15
Average(secs)	2.08	2.51	3.65
No. of readers	5	6	8
S.D (n-1)	1.72	2.31	5.16

VI. Story scenes reading

All the minimum average time to the first fixation were extracted for each story scene and their corresponding fixation counts and standard deviations as seen in **Error! Not a valid bookmark self-reference.**. The first fixation times were all found to belong to the story bubble in a scene. However, two scenes had Scene01, and Scene07 had first fixation times that were above a time of 1sec.

Table 9. Time to each scene's first fixation: minimum average time, count, standard deviation (S.D) and standard error of the mean (S.E.M).

Story Scene	Average fixation time (secs)	S.D (n-1)	S.E.M
Scene01	1.17	0.34	0.09
Scene02	0.47	0.05	0.01
Scene03	0.18	0.06	0.02
Scene04	0.72	0.02	0.01
Scene05	0.19	0.05	0.01
Scene06	0.67	0.03	0.01
Scene07	1.21	0.10	0.03

Scene08	0.89	0.17	0.04
Scene09	0.27	0.07	0.02
Scene10	0.57	0.04	0.01
Scene11	0.43	0.03	0.01
Scene12	0.78	0.08	0.02
Scene13	0.60	0.06	0.02
Scene14	0.80	0.02	0.01
Scene15	0.33	0.09	0.02

VII. Reading of the story bubbles

Figure 5-10 shows that at least 55%, and at most 89% of the reader's attention is fixated in the story bubbles itself. Scene 01 had the least fixation duration in the bubbles while Scene 07 was the scene with the most fixation duration by the readers. Scenes with just a story bubble had greater fixation duration between 65% and 89% of the total scene duration by the readers. In contrast, scenes with two story bubbles had smaller fixation duration between 55% and 76% of the total scene duration except for Scene 06, which was 85%.

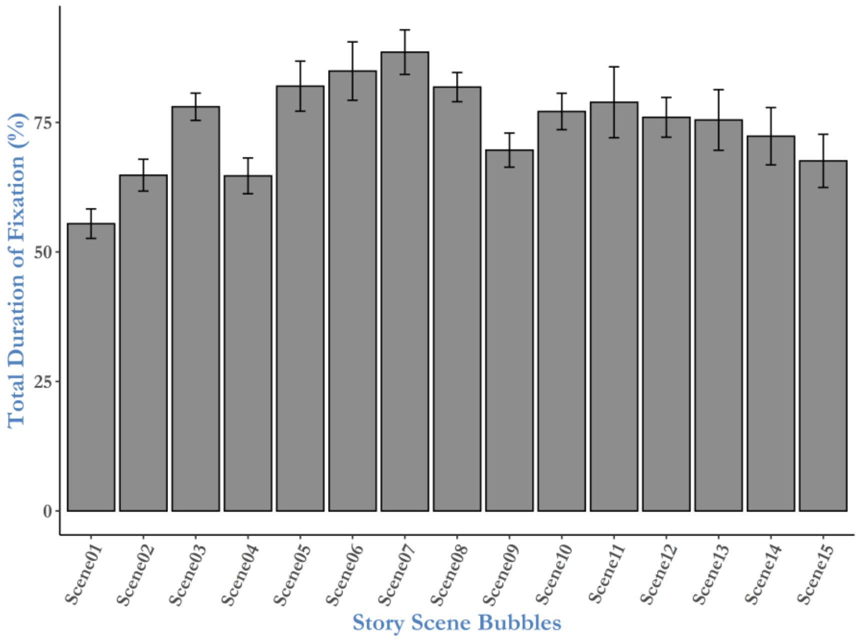


Figure 5-10. Percentage total duration of fixation in the story bubble of each scene.

In summary, eye movement metrics were able to provide actionable and evidence-based insights on how readers engaged and interacted with the story visualization. It also gave clues on design considerations in creating story focus cartographic representations.

5.2. Analysis of questionnaire responses

The questionnaire produced invaluable information on the readers' perception of the story, both of its visualized form and in its textual form. In this section, the responses, anonymized, are analysed.

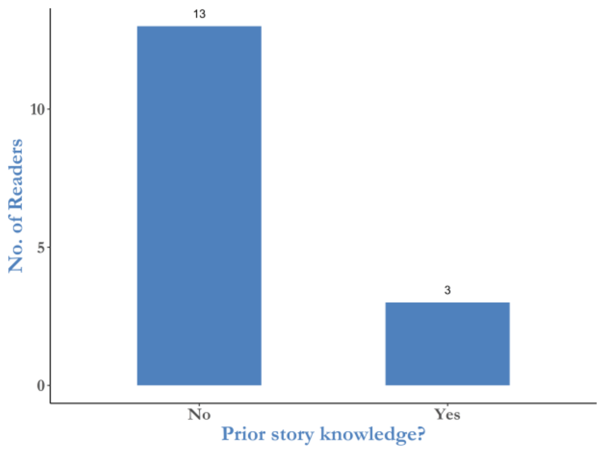


Figure 5-11. Readers story knowledge before the experiment

Thirteen (13) out of the sixteen (16) who took part in the study had no previous knowledge of the story, Legend of Meng Jiangnu. The readers, three (3) of them with prior knowledge of the story, after reading the visualization tend to be more critical and detailed on the missing aspects of the story. However, readers without prior knowledge only noticed that some characteristics of the text version were not transferred to the visualization only after reading the story's text.

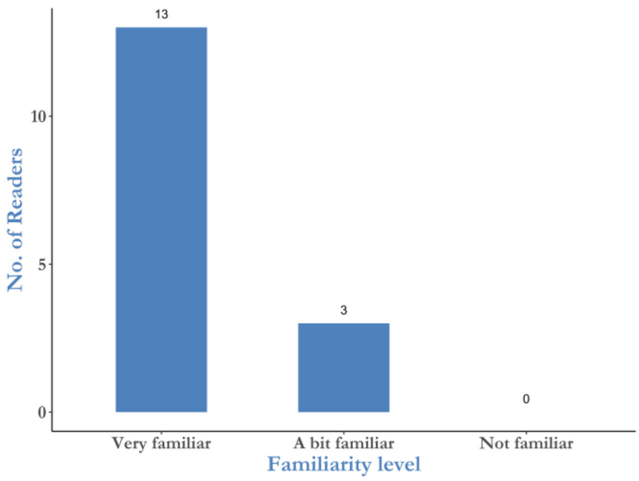


Figure 5-12. Readers internet map usage

Most of the readers (13), as seen in Figure 5-12, were "very familiar" with using maps over the internet while the others (3) were "a bit familiar". Asking the readers of their familiarity levels with interactive maps over the internet was essential to know what sort of interactions (zooming, panning, etc.) would be expected while they navigate the visualization. Upon the replay of the readers' gaze videos, their mouse events recording showed how they tried to perform some of the standard map interactions.

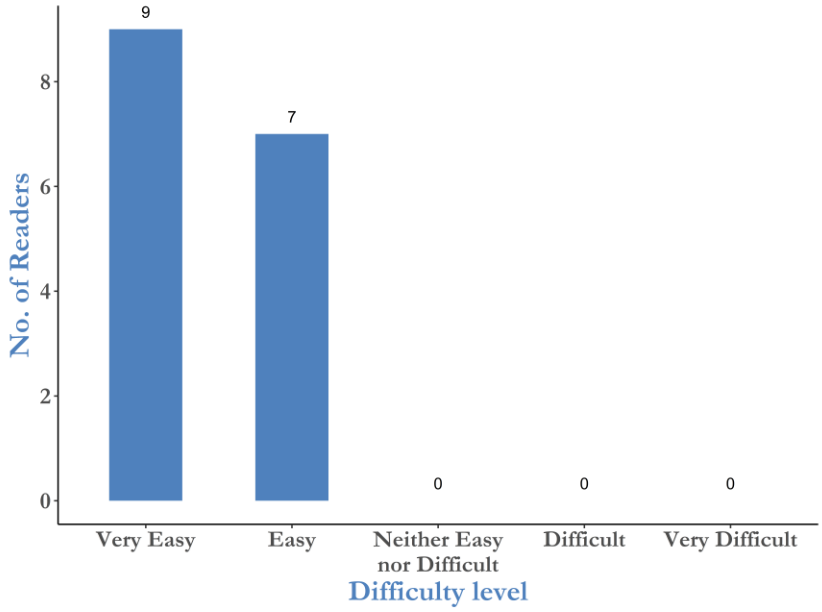


Figure 5-13. Readers' evaluation on navigating the story visualization.

All readers of the experiment found it considerably easy to navigate the medium. Specifically, nine (9) readers found navigating the story visualization to be “very easy” meaning that no usability issues were encountered while others (7) found it just “easy” referring to few usability issues. The usability issues were uncovered during the post-experience interviews.

Regarding the horizontal feature component used to navigate the story visualization, 87.5%, that is, fourteen (14) of the readers interpret it also to tell time. However, one (1) reader interpreted the visualization element to mean distance and the last reader, had no additional meaning to it other than to switch between scenes. Readers, however, noted that after reading the text version of the story, the events time-lapse were more explicit in the text than in the visualization.

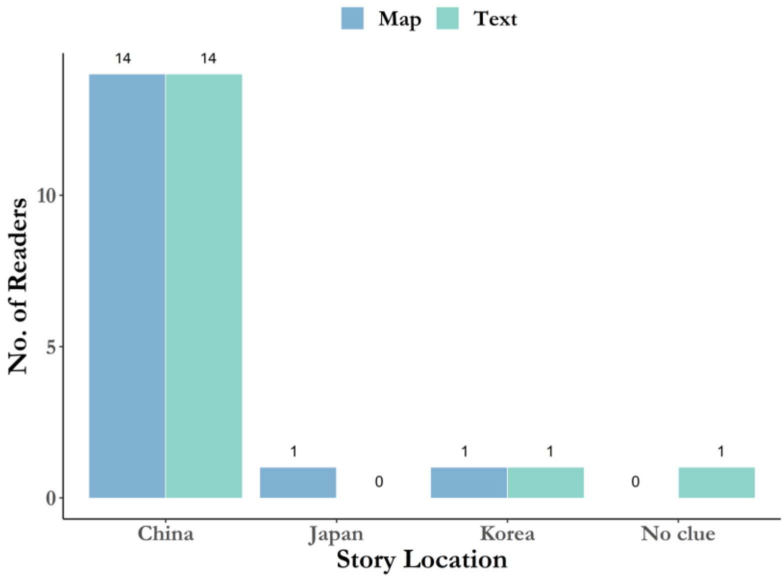


Figure 5-14. Readers' perception of story location.

In both media, there was no explicit mention of the place (administrative boundary) where the events of the story took place. However, there were clues from which the story location can be inferred. Within the context of the map visualization, most (14) readers used features such as the place names on the mini-map, the place names on the main map tile of the story bubble and the main character names to infer the "where" answer of the narrative. The other two (2) readers perceived the story in the visualization to be geographically located in Japan and Korea, attributing their assumptions to the character names. Likewise, for the text version of the story, fourteen (14) readers gave the correct response for the story location as China. These fourteen (14) readers credited their choice to "The Great Wall" found in the text and the *character names*. However, two (2) readers incorrectly answered the location of the story. One of the incorrect responses was Korea, and the reader cited the names of the main characters as the clue that led to their answer while the last reader had no idea where the story took place stating that they found no clue.

Table 10. Atmosphere perceived in the story visualization and their identifiers

Emotions	Emotion identifiers
Love, Joy, Happiness	Animation (16), Heart Symbol (16)
Sadness	Colour: Red (10), Animation (16)
Fear	Colour: Dark grey (9)
Hope	Colour: Yellow (8)

For the story's atmosphere, readers were asked to identify what emotions were evoked and their identifiers while they read the map visualization. Readers did self-report that love, joy, happiness, sadness, fear, hope and sadness were some of the emotions they felt while reading the story. Table 10 summarizes the emotions readers perceived and the most occurring identifiers included as counts in parenthesis.

The inclusion of the narratives perceived by the visualization readers is to stimulate their writing process: each reader writes, in their own words, what story they had perceived. The writing task equally helped to evaluate the readers' perception of the story and to discover what parts of the story were not transferred to the visualization. Two sample descriptions of the story perceived by a reader with and a reader without prior knowledge of the story have been appended in Appendix X.

5.3. Analysis of post-experience interviews

The semi-structured interview, which was used to probe the perception of the readers, is analyzed in this section.

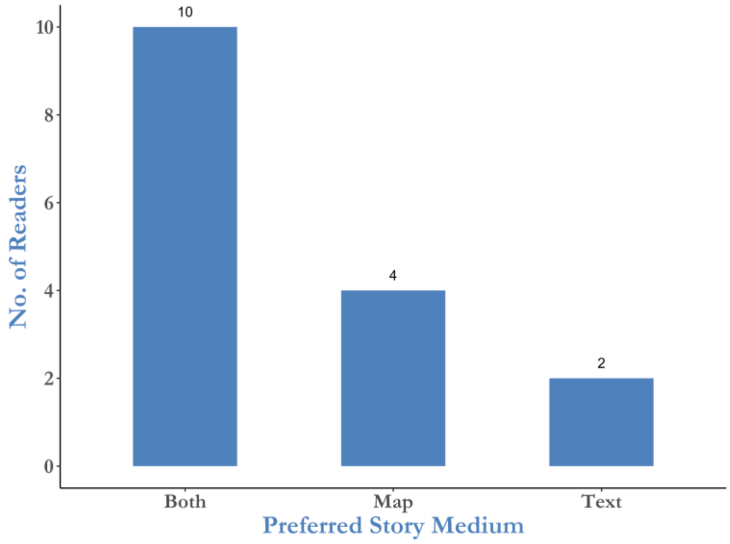


Figure 5-15. Readers' medium preference for communicating the story.

Overall, most of the readers could not pick one medium. They found it hard to decide on either the visualization or the text version of the story but rather went for both media. According to these readers, ten (10) of them, both media complemented each other. A reader had this to say,

> "I could easily understand the map and the pain the woman, Meng, felt. I initially understood that the man, Fan, was taken to a construction place because of the excavator but only realized, after reading the text, that it was some sort of government decree for "labour force" and that he died from exhaustion. Also, I thought the construction was for prison walls, like a yard. But then that was meant to be the Great Wall. It was hard to understand that from the map."

In the interviews, the readers mentioned that although the map visualization communicated the story, it did not convey some aspects of the story in detail which was only became obvious when they read the text version of the story. Aspects like exact times, the cause of events and precise spatial measurements were not easily deciphered from the visualization.

Readers were also asked for feedback on how the story visualization can be further improved for a better experience. Few (2) readers mentioned the need to increase the size of the timeline feature, thereby making it much easier to click with the mouse. A reader particularly preferred to use the keyboard arrow keys (left and right) keys to navigate the story and recommended its addition.

5.4. Discussion

The results of the experiments suggest that story bubbles are effective in guiding the reader's attention. The heat maps and gaze plots provided initial evidence that readers focused their attention on the story bubbles of the maps while ignoring other parts outside of it. The story bubbles had the fixation hotspots (i.e. greater fixation period) compared to other areas of the story visualization. This suggests that readers dwelt more reading and understanding the contents of the story bubbles. Further evidence on the probable effectiveness of the implemented focus technique was seen in the percentage total duration recorded in each scene of the story visualization. Readers fixated between 55% to 89% of their reading times on each scene, focusing on the story bubbles in proportion to other components. Additional proof that suggested the effectiveness of the story bubble was seen in time to the first fixation in each scene. The results showed that readers first visited the story bubbles meaning that their attention was first fixated there.

The visual strategy used in reading the story visualization was identical across all readers. Each reader started with the story bubble where they also had their gaze mostly fixated before moving to the legend, then the mini-map and finally the timeline. In scenes where they were animation buttons, readers had their gaze fixated last there. The evidence was consistent in the time to first fixation, gaze plots and replay of gaze video recording.

The experiments revealed that readers needed to adapt to added functionalities like buttons in the story visualization. Although few readers used the button at the beginning, more readers used the button as they approached the end of the visualization. This could be a pointer that readers needed some time to adapt to the implemented technique of visualizing movements in space. It could also mean that the instruction to use the button was incomprehensible or inconspicuous enough. Hence, there might be a need to include a salient hint feature telling the readers to use the button.

Asides the main map tile and character names, readers of the story visualization identified the mini-maps as an element of the visualization that informed them of where the story took place. A reading pattern was observed for the mini-maps. These mini-maps, provided in each scene, were to provide additional spatial clues to where the story took place. Overall, readers had their fixation the most on the mini-map in Scene 01, and in other scenes only a few readers looked at them again, evidenced in the heat maps, gaze plots and fixation duration. The drastic reduction in intensity by the readers on the heat maps, fewer readers and fewer counts.

Readers also adapted to the varying contents of the legends. In the first scene of the story visualization, readers were presented with the two (2) main characters and their meanings in the legend. As soon as a new character was introduced as they read the story visualization, they fixated their gaze longer on the legends compare to when they had previously encountered those characters and unlocked their meanings. This afforded the reader to focus on other parts of the visualization and only look at the legend when it is needed. The evidence of the readers' adaption was seen in the heat maps, the gaze plots and the fixation duration.

In terms of navigation, the story visualization used a timeline feature. Most readers reported the ease of navigating the story visualization. However, the results of the experiment showed that a reader missed reading a scene of the story's visualization. Further investigation into the possible reason for the miss could not be ascertained from the video replay of the reader's gaze recording.

Large reading durations and time to the first fixation were observed in scenes 01, 07 and 15. For Scene 01 the reason for the large reading time and time to the first fixation was identified to be caused by the low latency in loading cartographic elements to the DOM of the browser. That is, the story visualization being a SPA, loaded all components on the first scene of the story visualization before the map, and the elements of Scene 01 alone showed up. Scene 07 was due to the insertion of a new map tile. The map tile server had a low latency. However, readers with scene reading times that were numerically far apart from the other data for Scene 15, was because these readers forgot the instruction on how to end the eye-tracking exercise and took a while before requesting assistance.

Although most readers correctly answered the question of where the story occurred in both media, one performed better than the other. With regards to the number of clues in understanding a place, the story visualization provided the readers with more hints (main character names, place names on map tiles and place names in mini-map) while that of the text was just the main character names and The Great Wall. One would have guessed that The Great Wall, one of the "7 wonders of the world", in the text, was a strong hint to where the story occurred, yet, a reader did not consider it a clue to inform them of the story's place. The reader who found no clue, however, was able to find two (2) clues on the story's location in the visualization. Summarily, readers are more likely to perceive the spatial context of a place easily and more precisely on a map than in a text narrative. Mocnik & Fairbairn (2018) attributes the strength of a map in depicting spatial context to be better because of its 2-dimensional structure as opposed to the 1-dimensional structure of a text.

Where colours and animations were provided in the story visualization, readers utilized animations more in perceiving the atmosphere of a place. All the readers, in the questionnaire, self-reported that although some colours evoked the mood and emotions of a scene, they found animated map symbols to have provided stronger context. In some cases, static map symbols (like the heart – metaphor for love), was sufficient.

Most readers of the experiment could not decide if they preferred the cartographic representation over the text version of the story and so went for both. Majority of the readers commented that certain aspects of the story were only clearer in the text version. One of such aspects that favoured the text representation was in conveying temporal events explicitly ("2000 years ago", "three days", "a year"). The visualization for the story represented time using the timeline feature, but readers did not find it explicit enough as they did in the text version. Mocnik & Fairbairn, (2018) discussed the time affordance that textual representations gives to storytelling as being superior because this can easily be constructed in sentences. Spatial relations, i.e. distance ("800 kilometres away") was another aspect that the readers could not perceive from the story visualization but did from the text. Mocnik & Fairbairn (2018) related this as a scale limitation of maps in conveying real-world measurements. Also, readers could not understand the leading cause of events ("dead from exhaustion", "takes some warm clothing"). Mocnik & Fairbairn (2018) anticipated the complexity in communicating the reasons that certain events happen at a place using map visualization techniques.

Table 11 summarizes the affordance of narrative text that was found to be transferrable to a map.

Table 11. Summary of comparative findings

Structural Aspects of Narrative	Map	Text
Time	Implicit representation of event time(s).	Explicit representation of exact event time(s) and very dynamic.
Spatial context	Limited to thematic aspects.	Variable using words, sentences and paragraphs.
Atmosphere (including emotions and moods)	Less detailed conveyance of situations; maps and symbols can be animated to convey an atmosphere.	Easily conveys inner dynamics; very descriptive.
Scale	Level-of-detail can be varied.	Very dynamic.

6. CONCLUSION

Research overview, answers and recommendations are highlighted in Section 6.1, 6.2 and 6.3, respectively. Future research possibilities are suggested.

6.1. Overview

Maps have been used to tell stories about places for a long time. Today, it is possible to tell stories using interactive digital maps. Albeit, most of the maps on the internet are supplemented by multimedia aid. A limitation with multimedia maps is the issue of effective communication as well as engagement of the target audience. Users of such maps have to navigate the map to understand the spatial context and then read, listen or watch the additional media. The idea that the characteristics of narrative text can be incorporated directly into maps was proposed by Mocnik & Fairbairn (2018) as the "story focus concept". The story, "Legend of Meng Jiangnu" was implemented using story focus techniques and evaluated through empirical experiments.

The second chapter starts by reviewing works of literature on maps and map types. It briefly discussed how different map types are used, how they are disseminated, and their pros and cons. A section in chapter 2 was dedicated to storytelling, the origin, the purpose it serves, and the advancements made in recent years. Digital and non-digital storytelling were the two broad categories considered and how one impacts the other. An overview of narratives and story maps was also covered. Lastly, the story focus concept is summarized, and maps and text media were contrasted.

Chapter 3 is where the selected story implementation was reported. In the section of the research, a breakdown of suitable techniques to convey the characteristics of the narrative text is tabularized. A prototype design of the cartographic representation was created from the selected techniques to convey the story. Based on the chosen techniques, the web mapping framework and tools to visualize the story was explored. The story visualization was then created.

In chapter 4, the research methods were selected and justified. Because the research experiments involved human participation, ethical procedures were followed, including getting approval from the ethics committee and presenting each participant with a consent form. Qualitative methods of eye-tracking, questionnaires and semi-structured interviews were adopted for the experiments. Participants, referred to as readers, participated in the exercises voluntarily.

Analyzing the results of the research experiments were done in chapter 5. The data collected were analysed for each research method in the form of charts and descriptive statistics. Evidence-based insights were then derived from the results. The results were interpreted within the context of this research.

In the current chapter, chapter 6, the research questions are answered in summary. Limitations and suggestion for further research are also included.

6.2. Answers to research questions

The research aimed to answer the research questions highlighted in Section 1.4.2. Section 6.2.1 covers the first research questions (RQ1.1 and RQ1.2) while Section 6.2.2 covers the second research questions (RQ2.1, RQ2.2 and RQ2.3)

6.2.1. Implementation of a cartographic representation

RQ1.1. What web visualization techniques can be used to tell stories of places of interest and at different scales as the story unfolds?

In answering this question, the story text was broken into pieces, and suitable means to convey the aspects of the story were identified. Techniques such as map styles, symbols, animation and scale were selected. When selecting the techniques, priority was given to the characteristics and aspects of the text to ensure that they are adequately transferred to the cartographic representation.

RQ1.2. What web mapping frameworks exist that support representation of the narrative aspects and characteristics (atmosphere, mood, scale, time and spatial context) of a story?

Existing web mapping frameworks and tools were explored to incorporate the structural aspects of narrative text. In creating the visualization, Leaflet.js was used as the base mapping framework because it was simple, easy to modify and free to use (no payment required). The selected web mapping framework was simple in terms of understanding and implementing the functionalities as well as its size – lightweight. To transfer the characteristics of narrative text (atmosphere, mood, scale and spatial context) to a map, there was the need to modify the map, and Leaflet.js was successful in achieving this goal. Some of the modification implemented includes altering the scale to communicate a spatial context, interaction for reader's engagement and filter properties (opacity, blur, contrast, brightness, greyscale, hue and saturation) to evoke emotions, mood and atmosphere. The open-source status of the web mapping library eliminated the need for subscription fees and also provided the opportunity for developers to create plugins and extensions. Some of these plugins and extensions (leaflet-TileLayer-ColorFilter and leaflet-TileLayer-Mask) were useful in implementing the selected techniques.

6.2.2. Assessing the effectiveness of the cartographic representation

RQ2.1. How effective is the implemented cartographic representation in communicating and engaging the reader when compared with reading a text version of the story?

Most of the readers (62.5%) self-reported that neither the cartographic representation not the text version of the story alone was effective; rather, both media complemented each other in different aspects. For instance, they could perceive the temporal aspects of the story from the cartographic representation but not as explicit as it was in the text. Similarly, some inner dynamics of a place and the reason why an event occurred wasn't obvious in the cartographic representation but was glaring from the text. However, they found, for example, the spatial aspects (such as where the story took place) to have been better conveyed in the cartographic representation. The other 25% and 12.5% of the readers who participated in the experiments reported that the cartographic representation and the text version, respectively, communicated the story better.

RQ2.2. In which ways do the readers need to adapt to these new techniques of mapping stories?

Readers needed to adapt to the story mapping techniques in different ways. All the readers had their gaze mostly fixated and first on the story bubbles, – a focus guiding technique – and hardly looked at the greyed-out areas of the map. Readers used the map legend to understand the characters and fixated their gaze more when a new character was added; else, they rarely looked at the legend – a variability technique. Similarly, readers used the mini-maps to acquire additional hints on where the story took place geographically in the first scene and afterwards sparsely refer to the mini-map. Also, readers progressively identified and used additional button functionalities to understand spatial events – dynamics and expressivity.

RQ2.3. Which reactions did the readers perceive while reading the cartographic representation of the story?

The implemented cartographic representation was effective in transporting some of the aspects of the narrative text. One of such aspects was the atmosphere (mood and emotions). Readers perceived positive emotions of *love*, *joy*, *happiness* and *hope* via map colours, animations and graphic symbols. They also perceived negative emotions of *sadness*, and *fear* via the colours on the map and animations.

6.3. Recommendations and future research

The implemented story visualization in this research combined several tools and frameworks. However, having one framework that works out-of-the-box to create cartographic representations implementing the story focus concept would be ideal. The framework should ideally provide a variety of techniques that support telling stories using the story focus concept. It should be easy-to-use and, preferably, open-sourced.

Guidelines for implementing the story focus concept in telling stories can be derived from the experiment outcomes. For instance, by using story bubbles, a focus technique, the attention of the map readers will be well guided to parts of the map where they will find the information they need faster and efficiently. Similarly, by using (symbol) animation, emotions of a place can be easily understood by readers of the story visualization. Replicating the evaluated techniques in creating cartographic representations that implement the story focus concept could significantly improve the effectiveness of using maps to tell stories.

The emotions from the narrative text depicted in the story visualization in this research were self-interpreted, but it could be useful to consider other approaches. One such approach would be to carry out a pre-study to determine the feelings readers get when reading the text narrative before implementing the visualization. The pre-study could be by interviews or questionnaires.

The story focus concept for a story was implemented and evaluated in one story visualization in this research. A comparative approach could be considered. That is, a story is selected and implemented differently and then compared. Creating several representations of a story could better inform the Cartographer on which techniques transferred the aspects of the narrative text better. It could become clearer why some techniques performed poorly and why others were better.

Furthermore, it might be interesting to carry out a pre-selection of readers for the experiment. One pre-selection would be based on their educational backgrounds. For example, cartographic and non-cartographic students to evaluate how these two groups perceive spatial relations. Doing this might also provide insights on techniques a Cartographer should consider for story focus maps to effectively convey scale and temporal aspects of storytelling. Another pre-selection might be based on their prior knowledge of the story. Two groups of experiment readers can be designed and then evaluated to see how readers with versus those without prior knowledge of the story perceive the story.

Lastly, future research might consider adopting the visualization to be more inclusive. Potential readers of maps created using story focus techniques might have eye colour disorders. They might also benefit by including functionalities to enable readers to experience the story as readers without eye colour disorders. Also, useful to consider is providing readers with the capability to switch between modes and themes – like light to dark and vice-versa. Making the story visualization responsive across multiple devices should also be considered to accommodate readers with different screen sizes.

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APPENDIX I: READER INFORMATION SHEET

Participant Information sheet for “Maps Telling Stories – Story Focus Concept” experiment

This experiment is part of a master thesis publication at ITC, University of Twente and has been approved by the ITC Ethics Committee.

You are being invited to participate in a research study titled “Maps Telling Stories – Story Focus Concept”. Before you decide whether or not to partake, it is important to understand why the experiment is being conducted and what it will involve. The experiment will take you approximately **35** minutes to complete.

The Study

The purpose of this research experiment is *to test the effectiveness of communicating stories with a map by incorporating the narratives of the stories as they unfold compared to its text version.* The experiment involves:

- Map reading: Here, a digital map is presented to you on a screen, and your focus and gaze are recorded using an eye-tracking device. A short anonymous questionnaire is then given where you note your perception of the story.
- Text reading: At this point, you are presented with the text version of the story. As a follow-up, a similar short anonymous questionnaire is filled by you on your perception of the story.
- Brief Interview: An audio-recorded interview of your perception of the story on both mediums (map and text)

There are no known health risks associated with this research experiment. The eye-tracker equipment is a safe and non-invasive technique used in recording instantaneous eye movements and have been used at universities and companies all over the world for usability tests. The data provided in the questionnaires and in the recorded interview will be anonymised by the substitution of any identifiable information. The audio-recorded interview is securely stored on a password-protected drive and is entirely destroyed after it has been transcribed to text.

Your participation in this study is entirely voluntary, and you can withdraw at any time without giving any reason. You can equally contact the researcher (whose contact details are below) should you wish to withdraw and have your data erased.

Thank you for volunteering to participate in this experiment.

Researcher’s contact information: Adebayo .Y. Ishola ishola@student.utwente.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Geo-Information Science and Earth Observation: ec-itc@utwente.nl

UNIVERSITY OF TWENTE.

APPENDIX II: CONSENT FORM

Consent Form for "Maps Telling Stories – Story Focus Concept" Experiment

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated 28/05/2020, or it has been read to me. I have been able to ask questions about the study, and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions, and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves the recording of my eye-movements using an eye-tracking device, completing questionnaires and an audio-recorded interview. The eye-tracking device will record eye movements to help understand the time spent viewing different parts of the screen and will be discarded after the analysis is completed. The questionnaire is filled by you. The audio recording will be completely destroyed after it has been transcribed to text.	○	○
Use of the information in the study		
I understand that information I provide will be used for a master's thesis publication.	○	○
I understand that personal information collected about me that can identify me, such as my age will not be shared beyond the study team.	○	○
I agree that the information provided during the experiment can be quoted in research outputs anonymously.	○	○
Consent to be Audio Recorded		
I agree to be audio recorded.	○	○
Consent to record eye-movement	○	○
I agree to use the eye-tracking device.		

Signatures

______________________ ______________________ _________

Name of participant [printed] Signature Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

____Adebayo .Y. Ishola____ ______________________ _________

Researcher name [printed] Signature Date

Study contact details for further information: Adebayo .Y. Ishola, ishola@student.utwente.nl

UNIVERSITY OF TWENTE.

APPENDIX III: EXPERIMENT INVITATION

Hi there,

I am currently researching on using maps to tell stories effectively.

A web map has been created, and I will like you to help test how effective it is using the eye-tracking device and answering a few questions on a questionnaire. The entire process is within 35 minutes.

Happy to help? Please scan the QR Code below and select a convenient time and day (Deadline: 22 July 2020). Kindly enter your email address where it says "name" on the Doodle. Other participants cannot see your details.

If you have just any question, please feel free to send me an email:
ishola@student.utwente.nl

Thank you in anticipation. :)

UNIVERSITY OF TWENTE. ITC Cartography M.Sc.

APPENDIX IV: EXPERIMENT CHECKLIST

<u>A day before experiment</u>

For Researcher
☐ Check experiment location availability.
☐ Audio recorder storage space.
☐ Printed and digital copies of questionnaire, consent form and information leaflet.
☐ Print experiment procedure.

For Reader (via email)
☐ Confirmation of availability to participate.
☐ Experiment exact address.
☐ Overview of what will be done.

<u>Moments before experiment</u>

For Researcher
☐ Laptop computer.
☐ Eye tracking device.
☐ Audio recorder check.
☐ Provision of hand sanitizer.
☐ Seats are 1.5meter apart in accordance with Dutch government regulation on COVID-19.
☐ Copies of questionnaire, consent form and information leaflet.
☐ Writing pens.
☐ Restart computer and run a trial with eye tracking device.

For Reader
☐ Shows and has no signs of COVID-19 symptoms.
☐ Understands purpose of experiment and signs consent form.

Just after experiment

For Researcher
☐ Consent forms and questionnaire are properly stored. ☐ Audio and eye tracking recordings saved properly and backed-up

APPENDIX V: QUESTIONNAIRE & INTERVIEW

READER'S PROFILE

This section requires information to understand the reader's profile.

1. I belong to the age group of:

   ☐ 16 - 30

   ☐ 31 - 45

   ☐ 46 - 60

   ☐ 61 - 75

   ☐ 76 and above

2. What is your highest completed degree?

   ☐ High School

   ☐ Bachelor

   ☐ Master

   ☐ Doctorate

   ☐ Other ____

3. What is your educational background? (the title of highest degree completed above)

   ____

4. What is your occupation? (e.g. Cartographer, GIS professional, medical doctor)

   ____

5. How familiar are you with using maps over the internet?

   ☐ Very familiar

   ☐ A bit familiar

   ☐ Not familiar

6. Before now, did you know the story "The Legend of Meng Jiangnu"?

☐ Yes

☐ No

Write the story you perceived.

QUESTIONNAIRE (After reading map visualization)

____

1. What emotions (e.g. sadness, happiness, anger, aggression, fear, hope, joy, excitement) did you get from the map visualization and what did you use to identify the emotions (e.g. colour, animation, map feature)?

SCENE	EMOTION	EMOTION IDENTIFIER
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

2. From the map visualization, which country do you think the story took place?

____

3. What feature informed you about the location of the story? *(Select all that apply)*

☐ Main map tile

☐ Mini-map

☐ None of the above

Specify others ______________________________

4. Did you notice the button/icon to repeat animation yourself?

☐ Yes

☐ No

5. What metaphor did the horizontal feature used in switching scene represent? *(Select all that apply)*

☐ Time

☐ Distance

☐ None of the above

Specify others ______________________________

6. What time metaphors were present in the map visualization.

____

____

7. How easy was it to navigate the map visualization? *(Select only one)*

☐ Very Easy

☐ Easy

☐ Neither Easy nor Difficult

☐ Difficult

☐ Very Difficult

8. What is the nature of the story? *(Select all that apply)*

☐ Romance

☐ Thriller

☐ Drama

☐ Horror

☐ Mystery

☐ None of the above

Specify others ________________________________

The Legend of Meng Jiangnu

More than 2000 years ago, there lived Fan Xiliang and Meng Jiangnu, who later got married.[1] Three days after their wedding, the government comes to their home and takes Fan away for the labour force of building the Great Wall.[2]

Seeing that her husband was taken away, Meng experienced such a hard time, and she cried for days as she missed him terribly.[3] Meng loves her husband so much, so she takes some warm clothing and departs for the Great Wall where her husband works after a year of not hearing from him.[4]

She finally gets to the Wall and hears the bad news that her husband is dead from exhaustion while building the Great Wall.[5] She is so desperate and cries three days at the Wall.[6] Suddenly, the Wall collapses 800 kilometres away, and she can see her husband's bones.[7]

QUESTIONNAIRE (After reading text)

____

1. What emotions (e.g. sadness, happiness, anger, aggression, fear, hope, joy, excitement) did you get from the text and what did you use to identify the emotions (e.g. dancing indicates happiness)?

SENTENCE	EMOTION	EMOTION IDENTIFIER
1		
2		
3		
4		
5		
6		
7		

2. From the text, which country do you think the story took place?

____

3. What word(s) informed you about the location of the story?

____

4. What aspects of the story in the text version were missing in the map visualization?

____

____

____

INTERVIEW

1. Which medium conveyed the story better? *(Select only one)*

   ☐ Map visualization

   ☐ Text version

   ☐ Both media (they complemented each other)

2. Any suggestions on the map visualization?

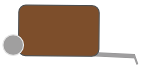
APPENDIX VI: ICONS AND SYMBOLS

Red Heart – metaphor for love.

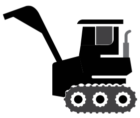
Light bulb – metaphor for idea.

Speech bubbles with a character inside and a cross over it – metaphor for talking with the statement indicating death of character.

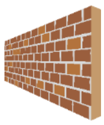
Thinking cloud – metaphor for thoughts of a person with the person being thought of within.



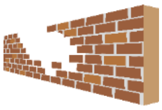
Bag – metaphor for travelling.



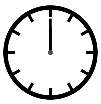
Excavator – metaphor for construction.



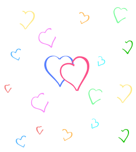
Bricks – metaphor for wall.



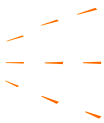
Incomplete bricks – metaphor for broken wall.



Clock – metaphor for time.



Partial hearts – metaphor for celebrations.

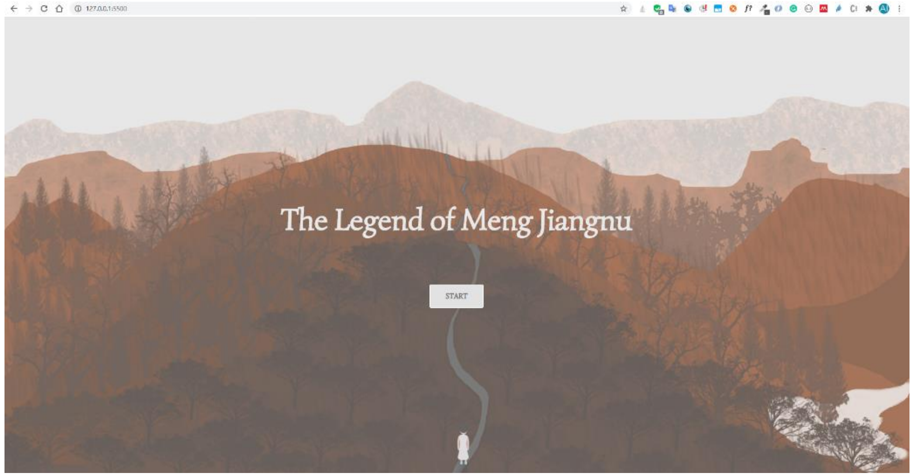


Spread dashed lines – metaphor for loud crying.

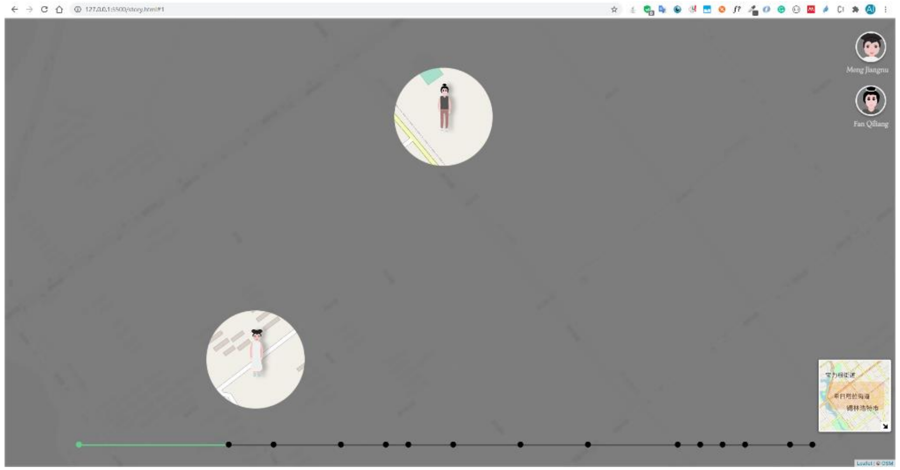
Non-uniform geometry – metaphor for construction sand.

Skeleton – metaphor for dead person's remains (i.e., bones).

APPENDIX VII: STORY VISUALIZATION

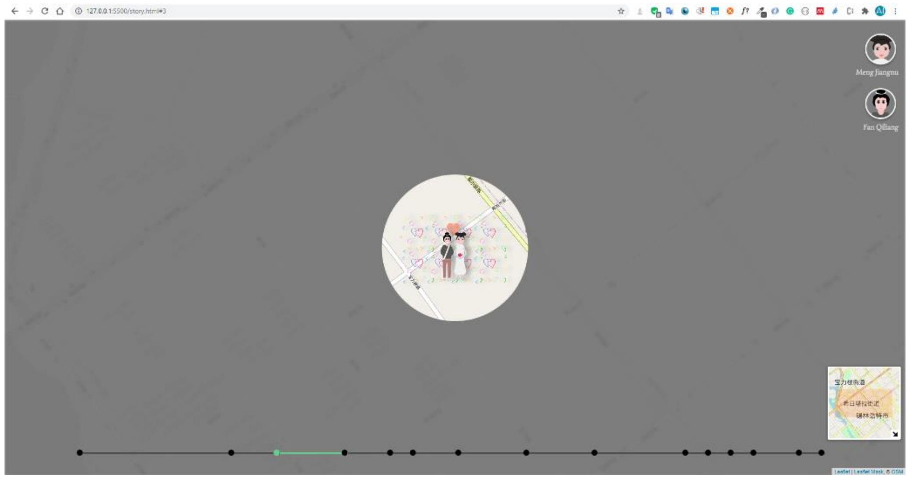


Start page

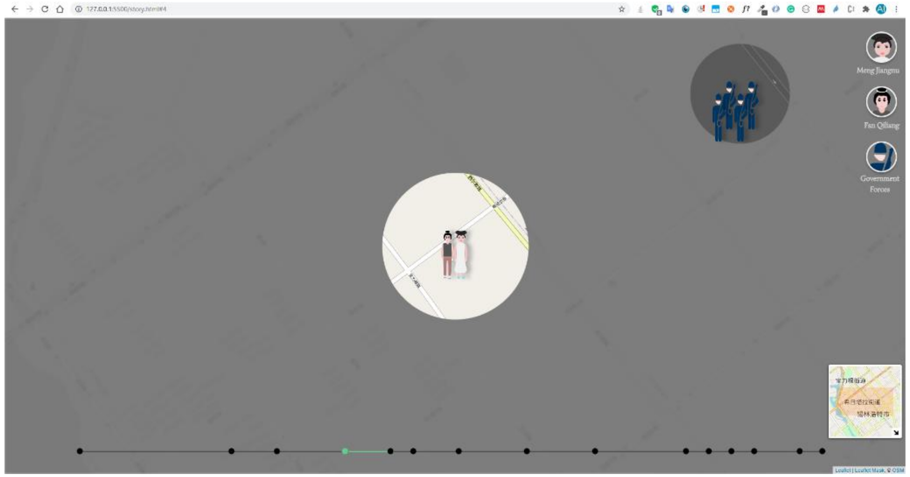


Scene 01

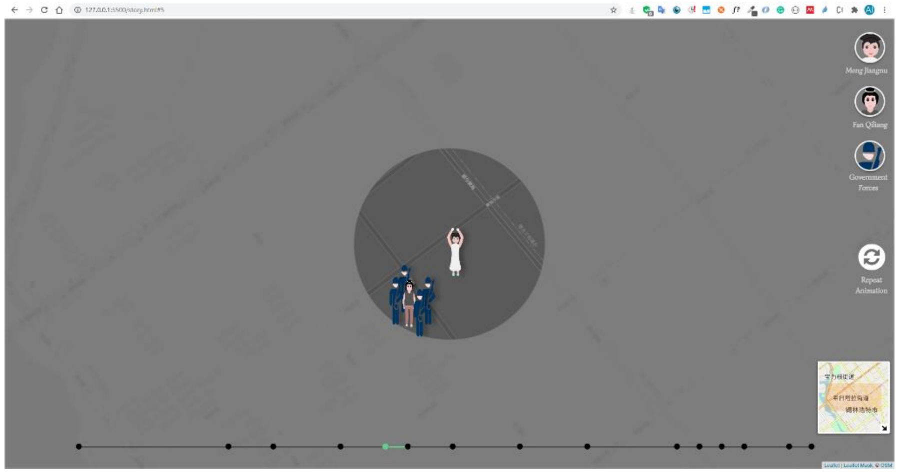
Scene 02



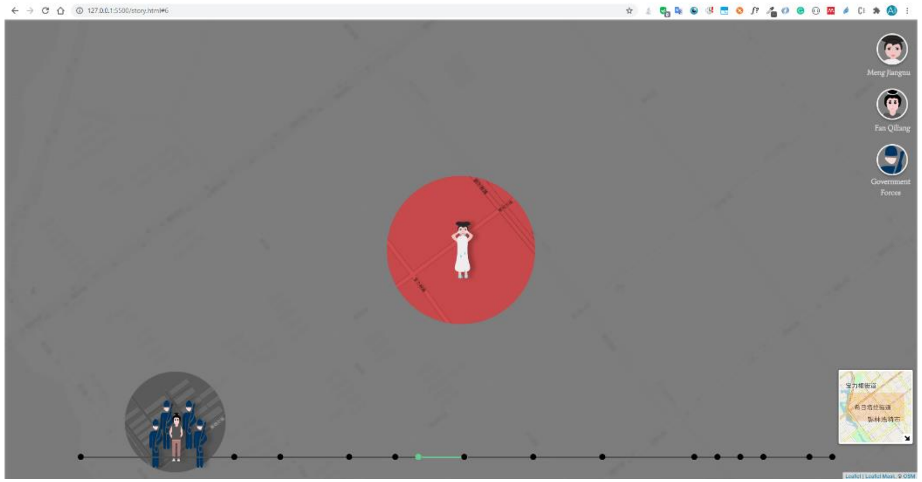
Scene 03



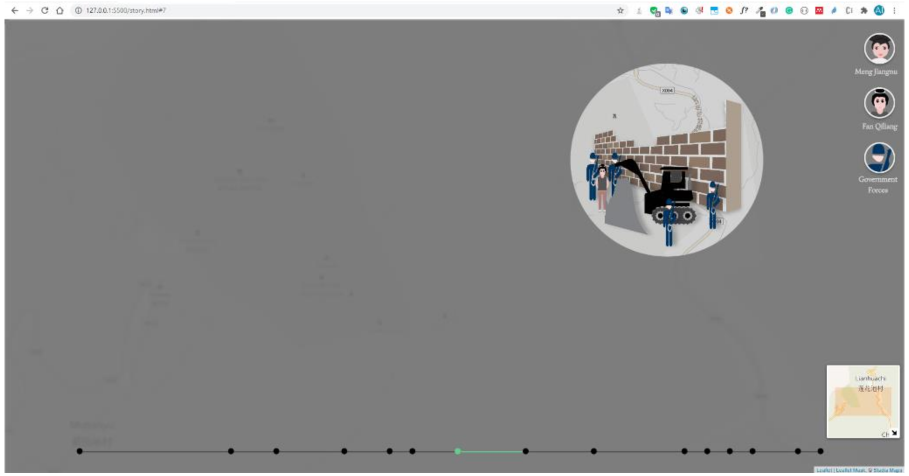
Scene 04



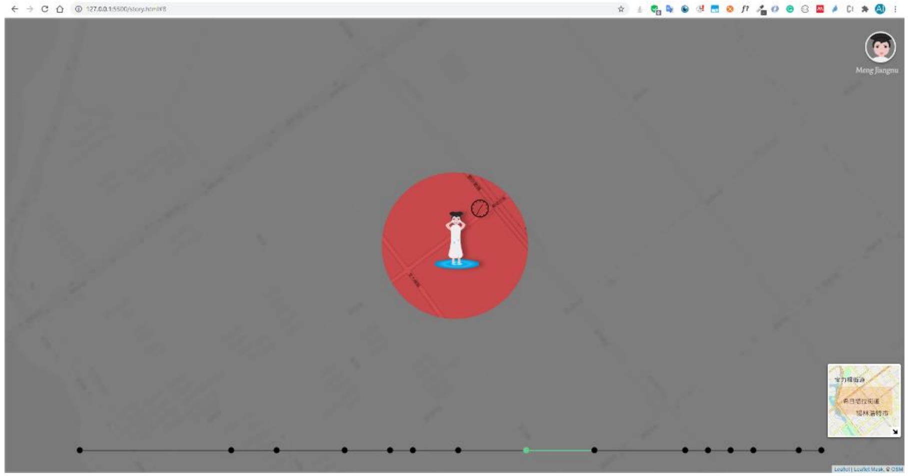
Scene 05



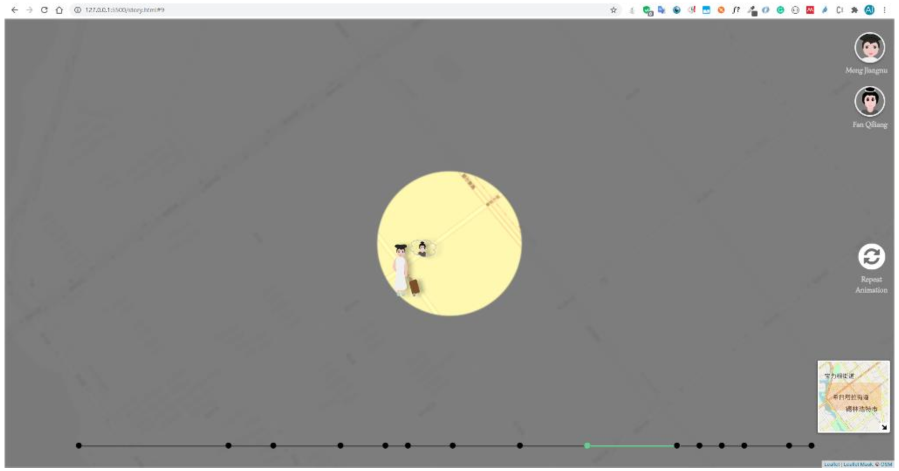
Scene 06



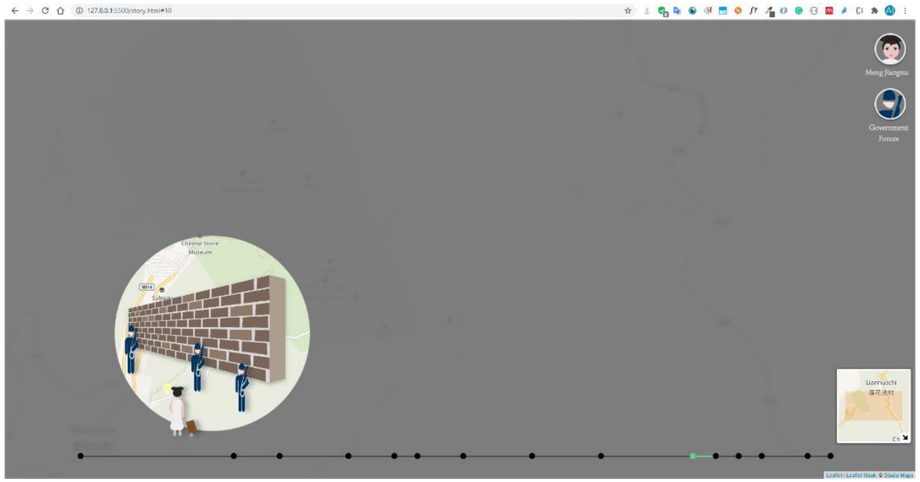
Scene 07



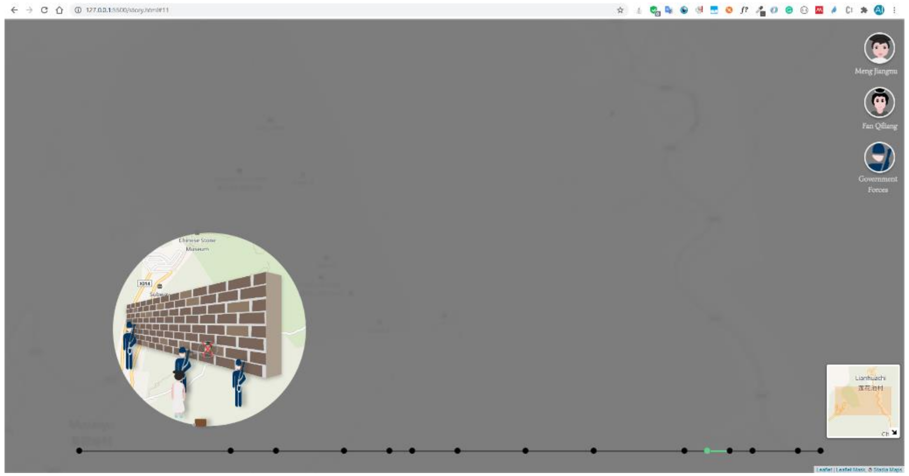
Scene 08



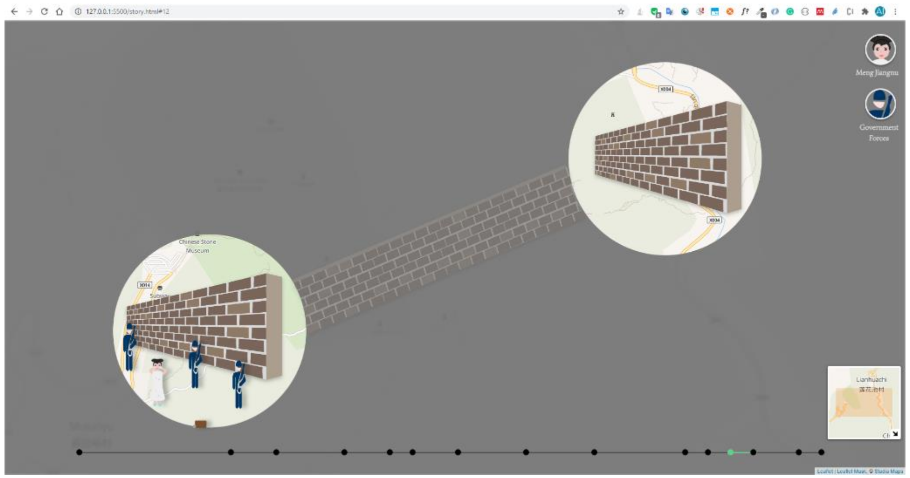
Scene 09



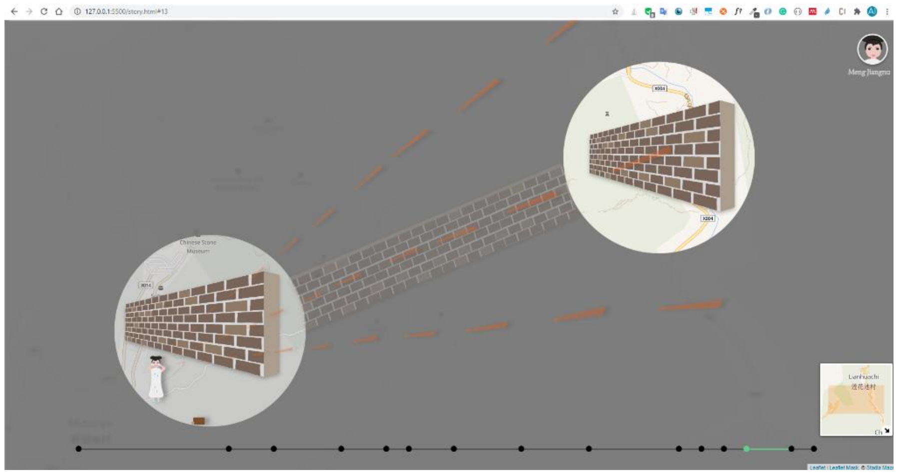
Scene 10



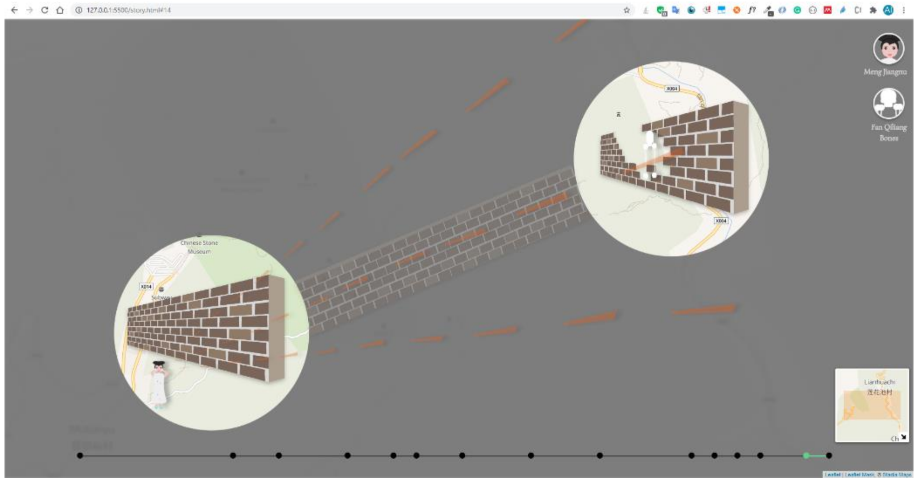
Scene 11



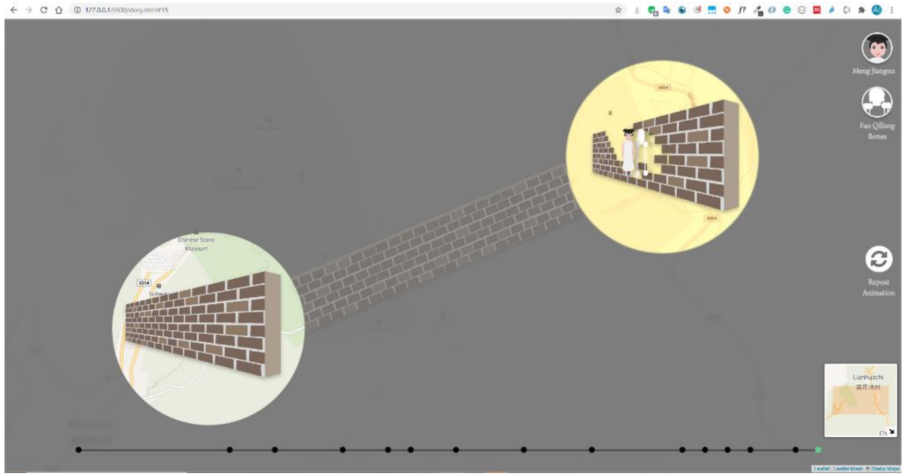
Scene 12



Scene 13

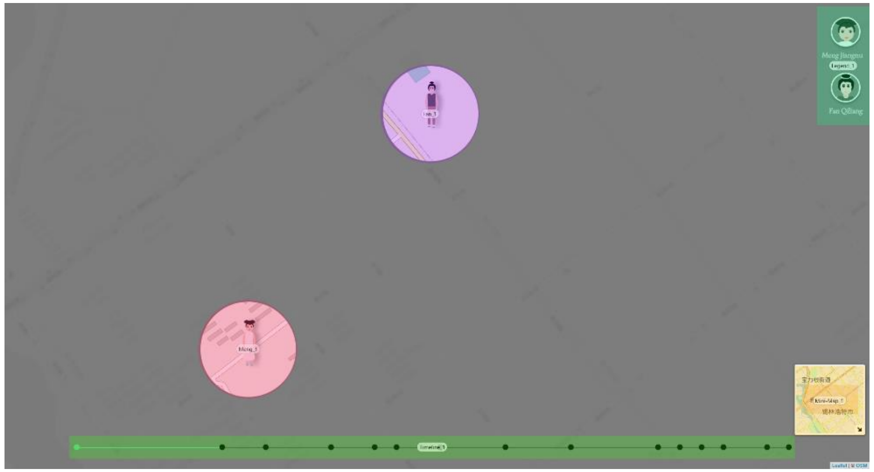


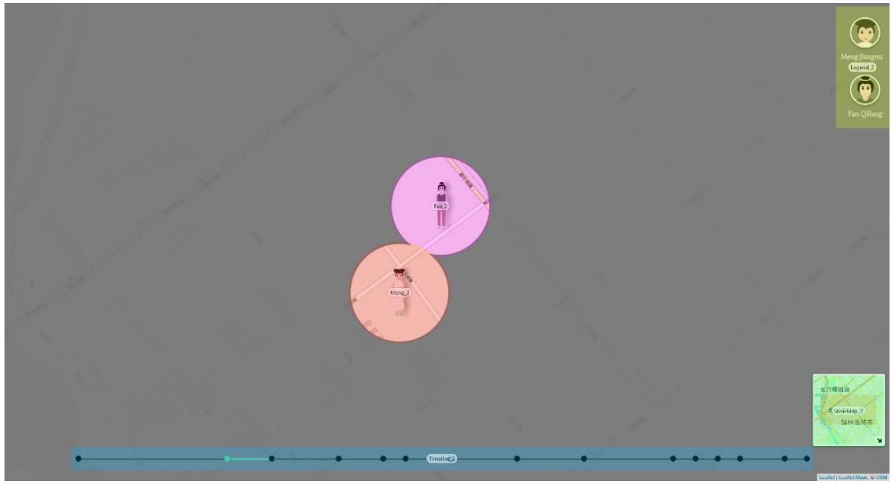
Scene 14

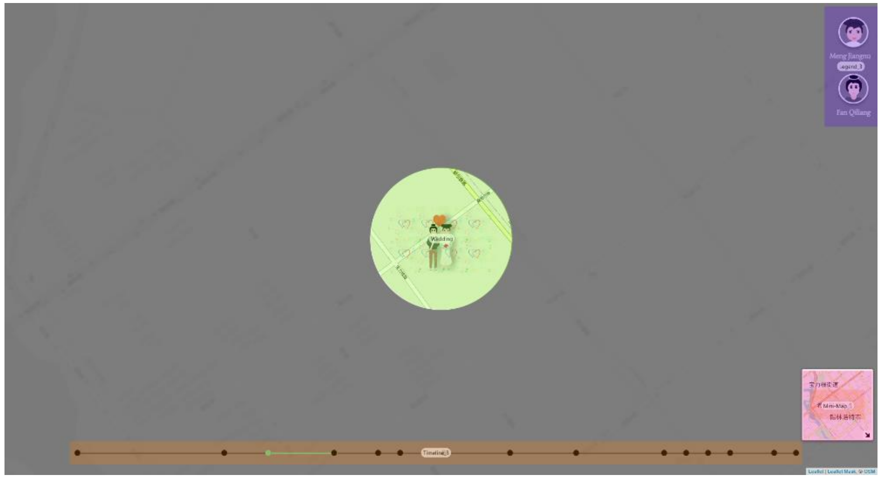


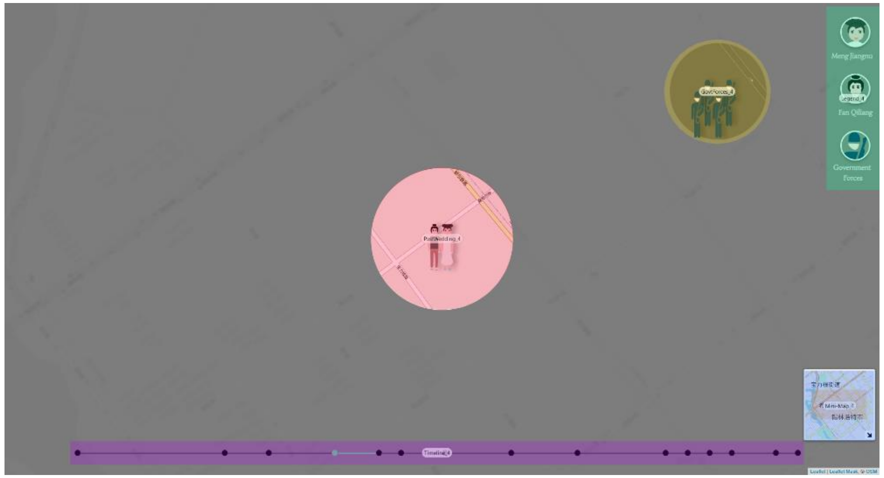
Scene 15

Start page

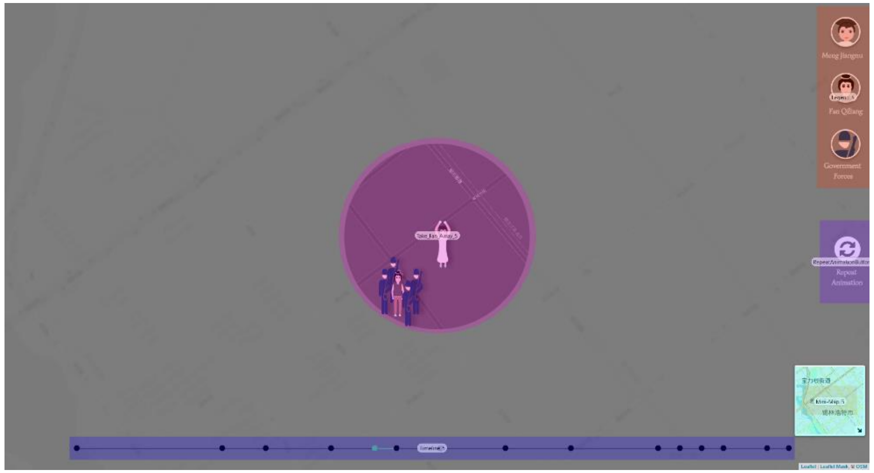

Scene 01


Scene 02

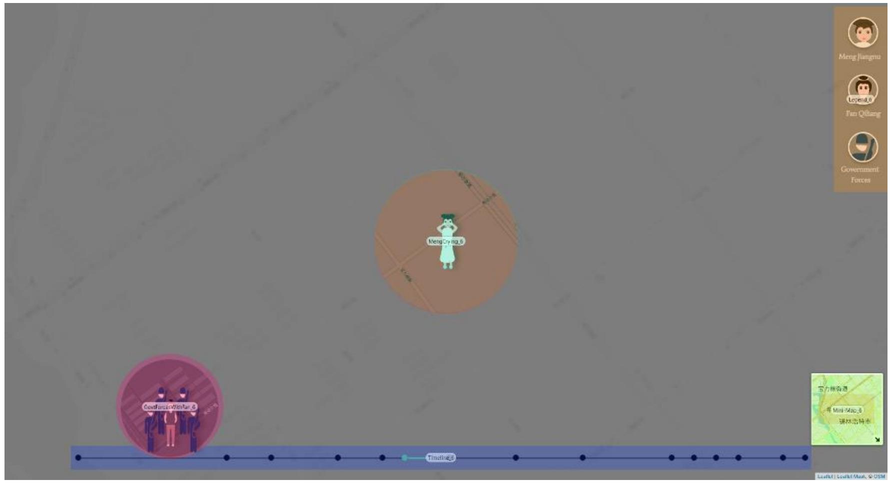

Scene 03



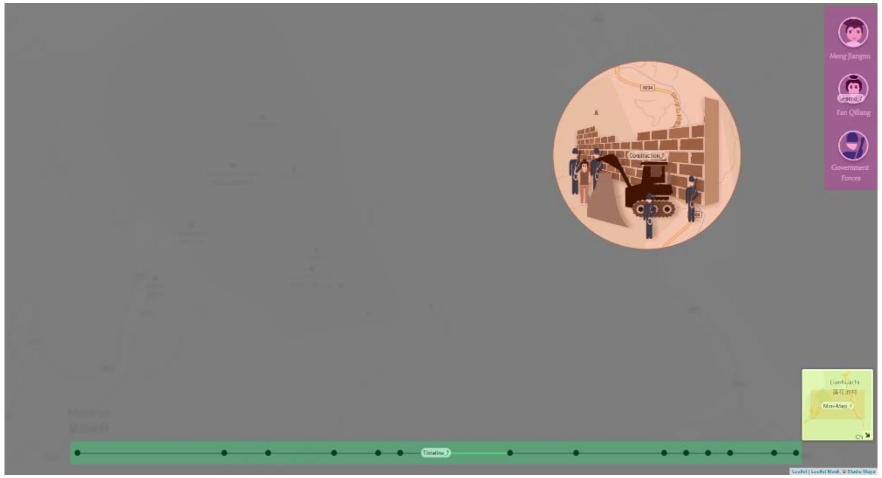
Scene 04



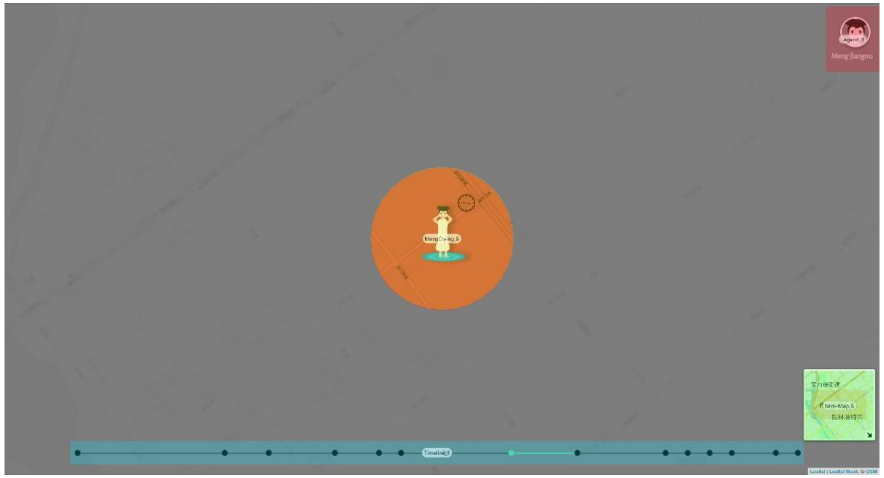
Scene 05



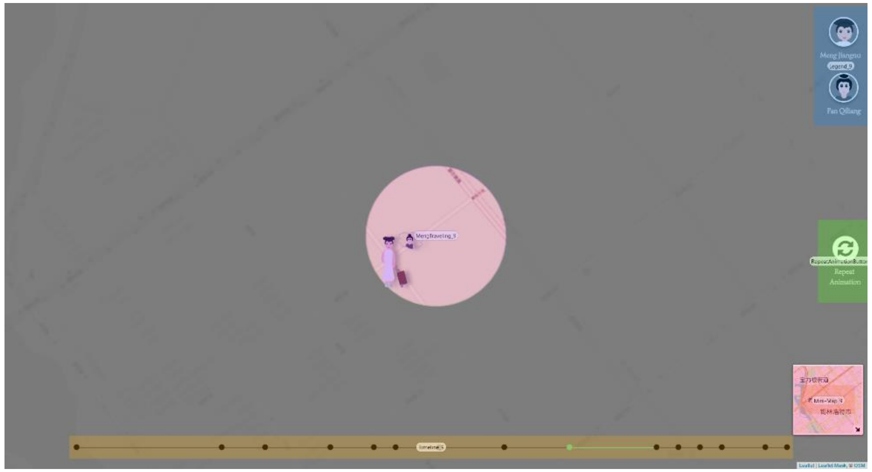
Scene 06



Scene 07

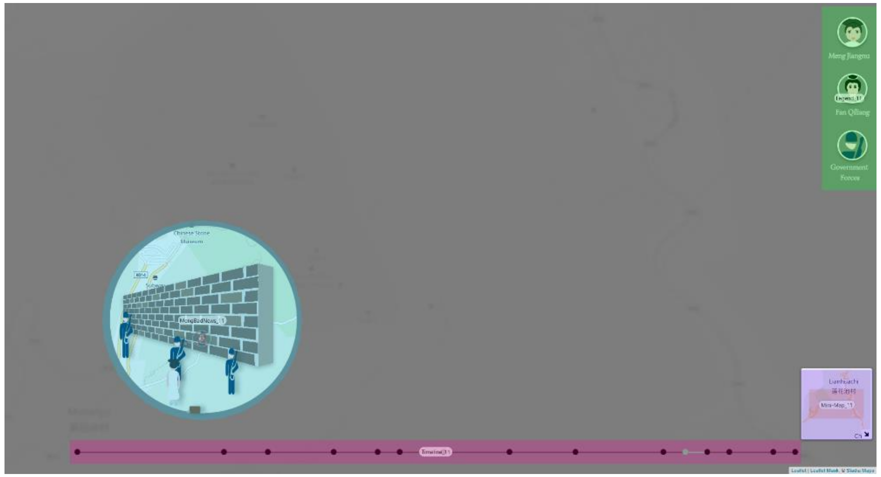


Scene 08

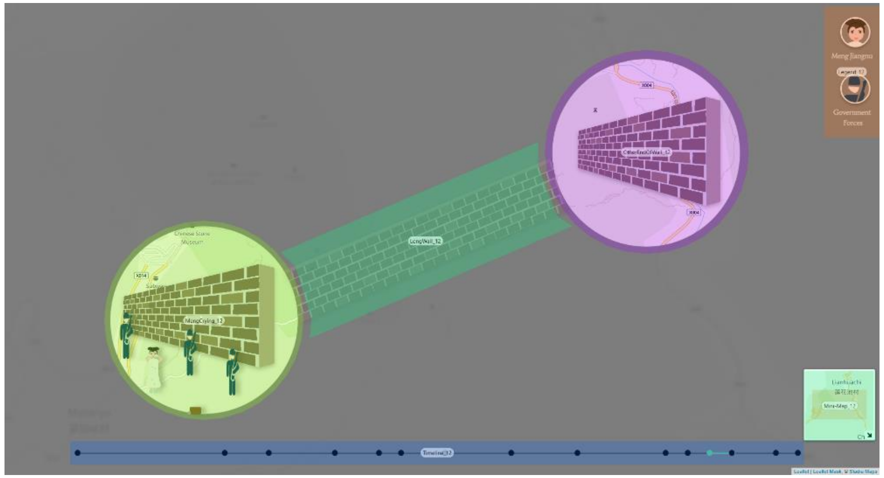


Scene 09

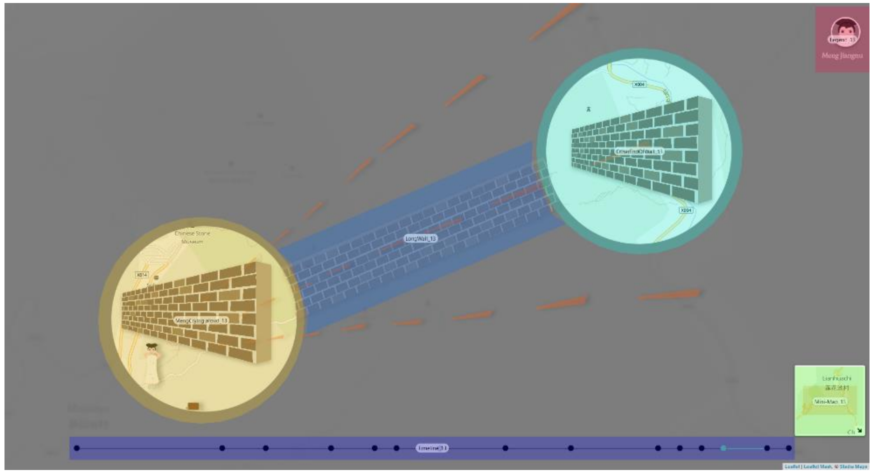
Scene 10



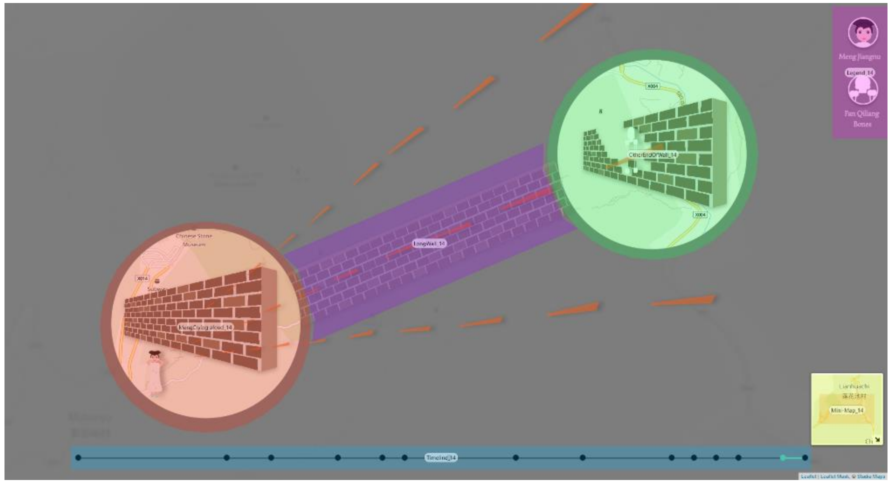
Scene 11



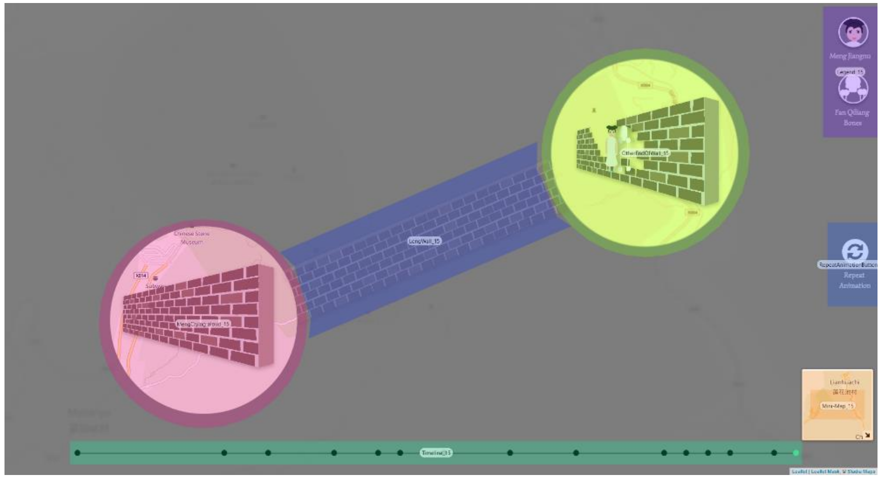
Scene 12



Scene 13

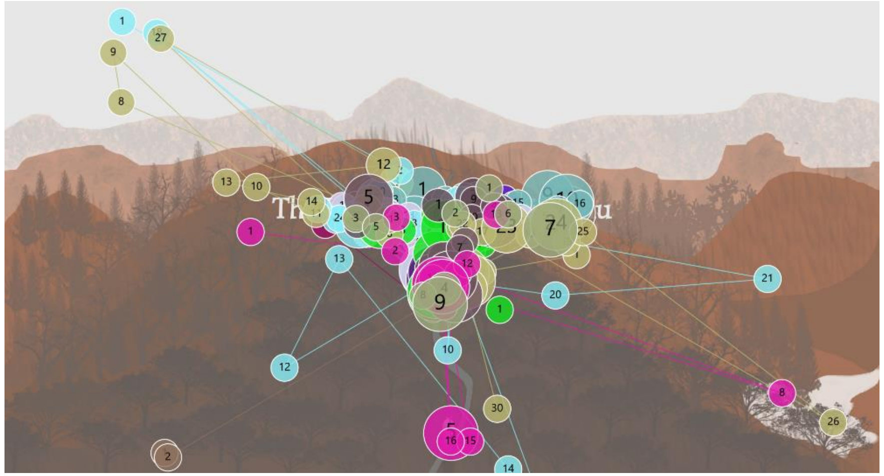


Scene 14

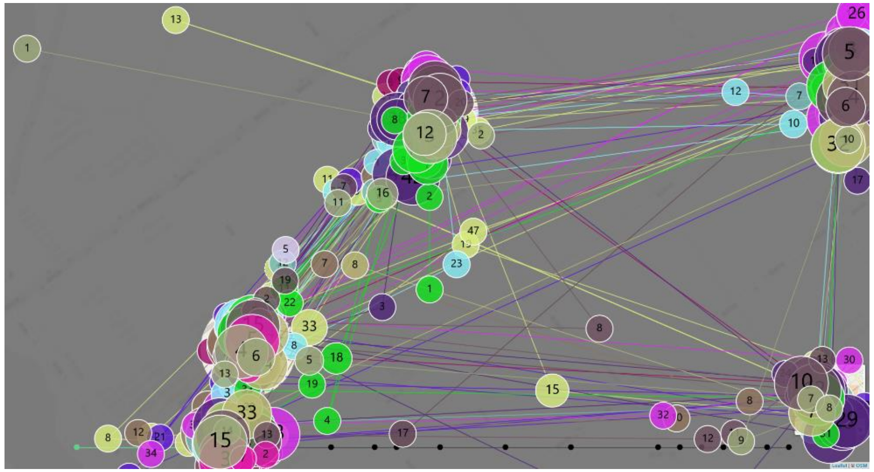


Scene 15

APPENDIX IX: GAZE PLOTS



Start page



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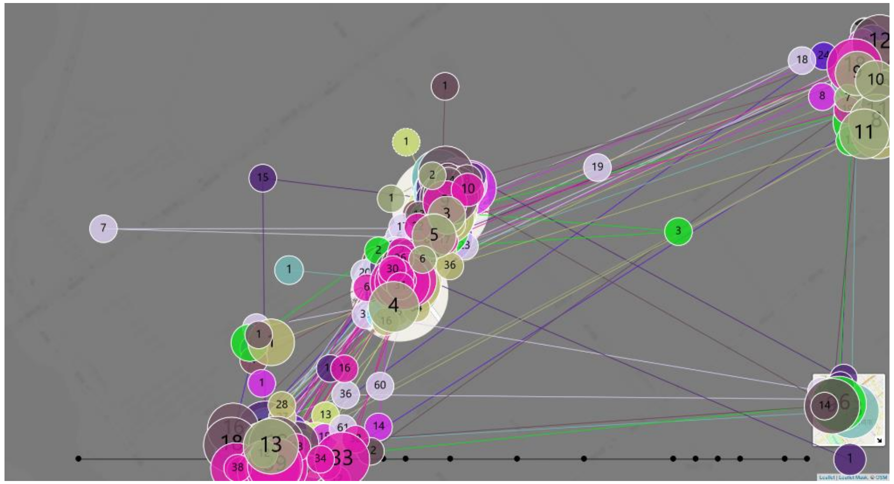

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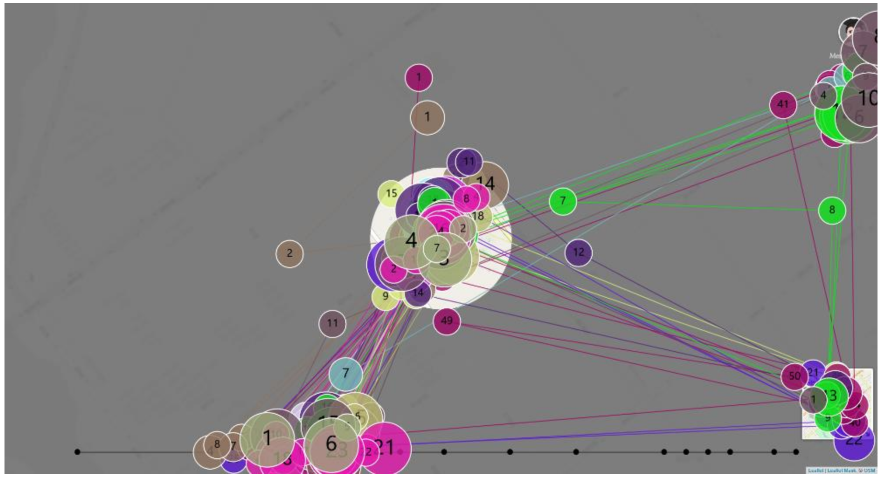

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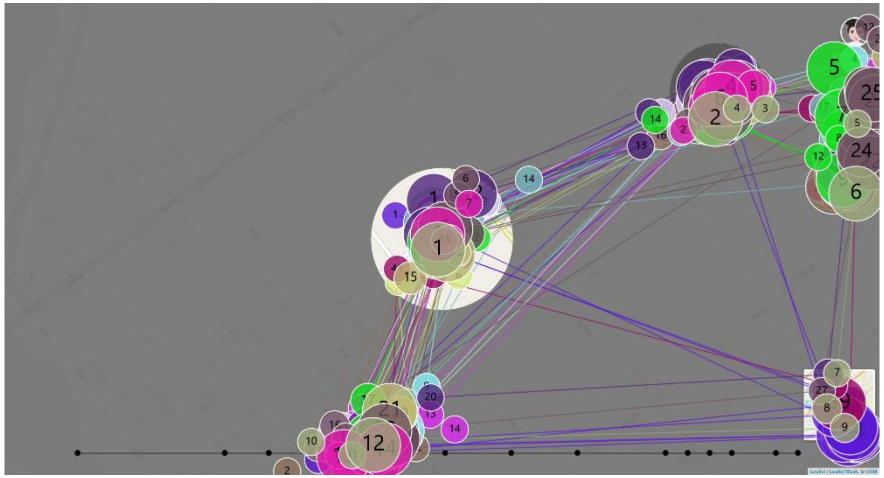

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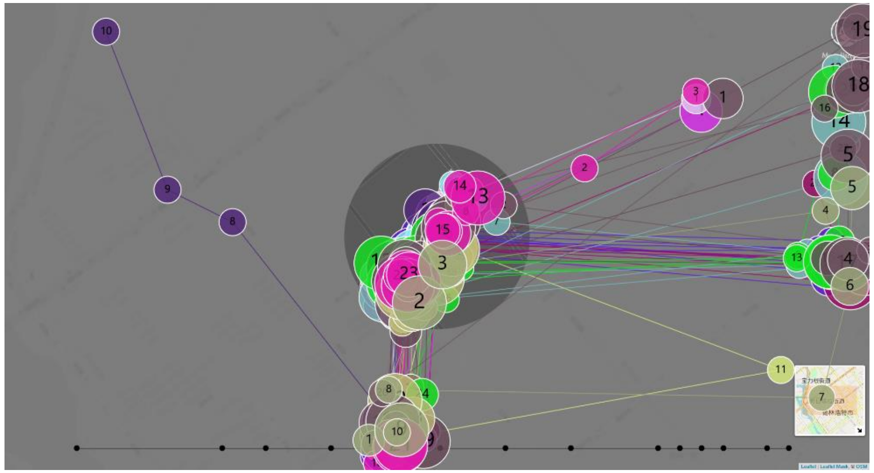

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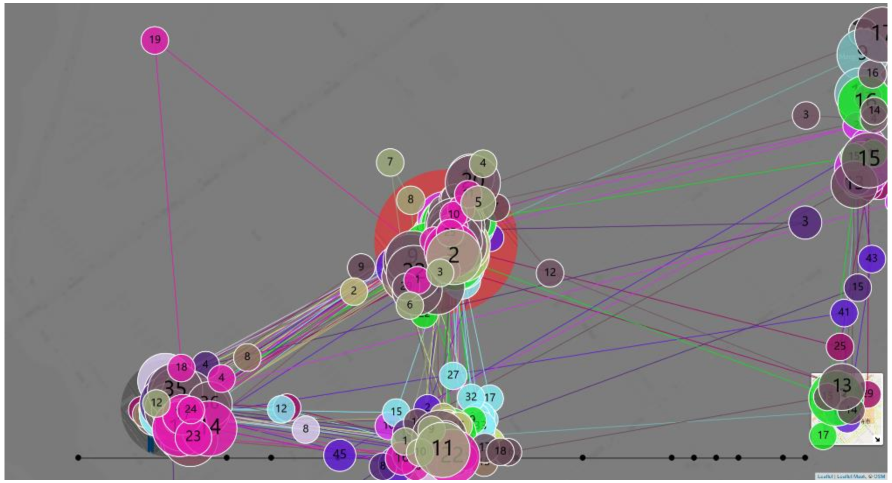

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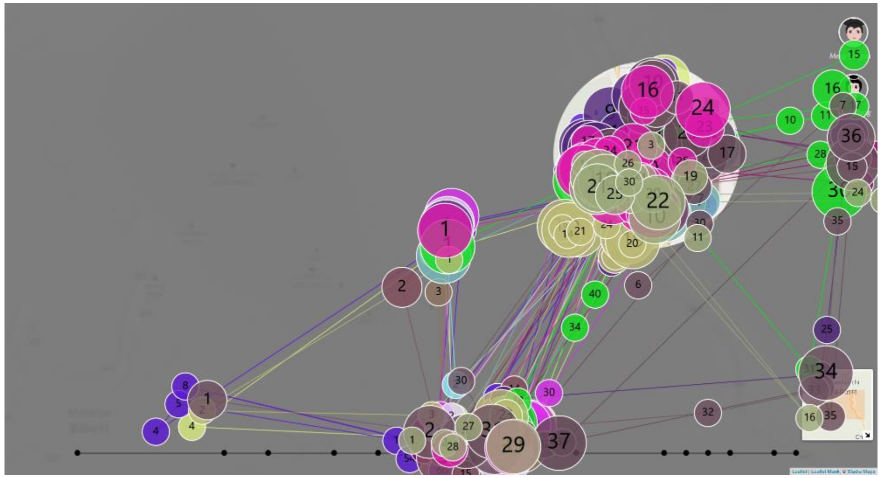

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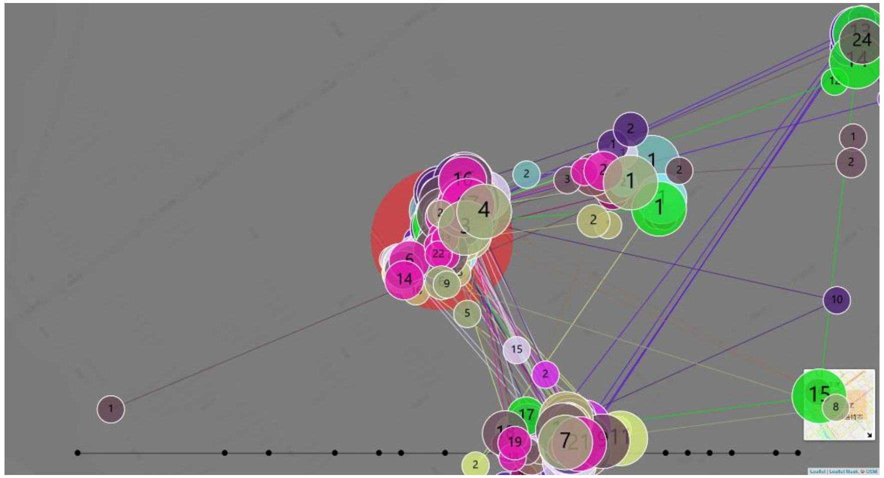

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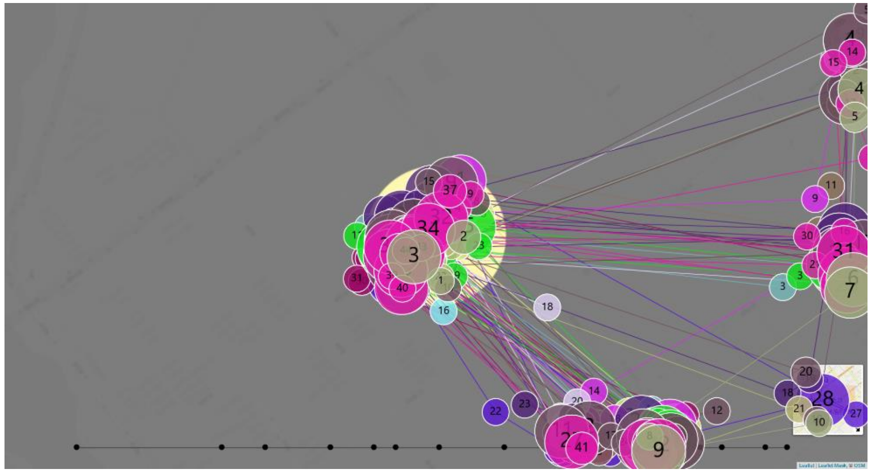

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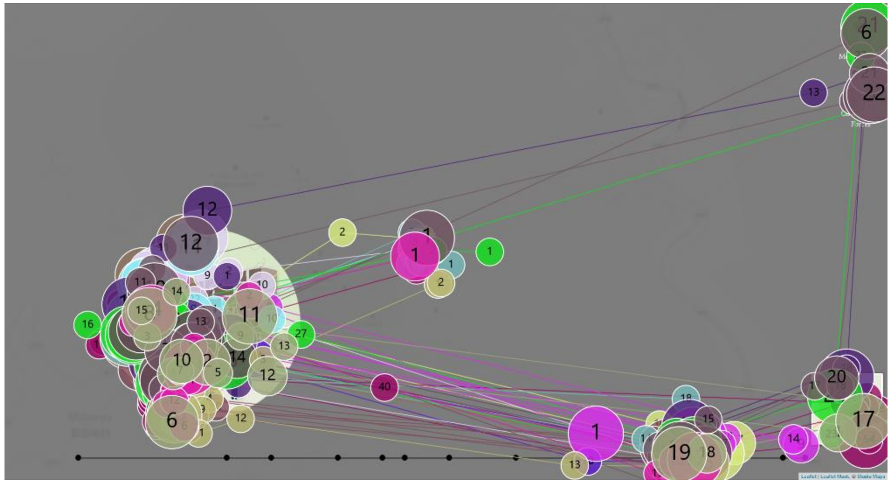

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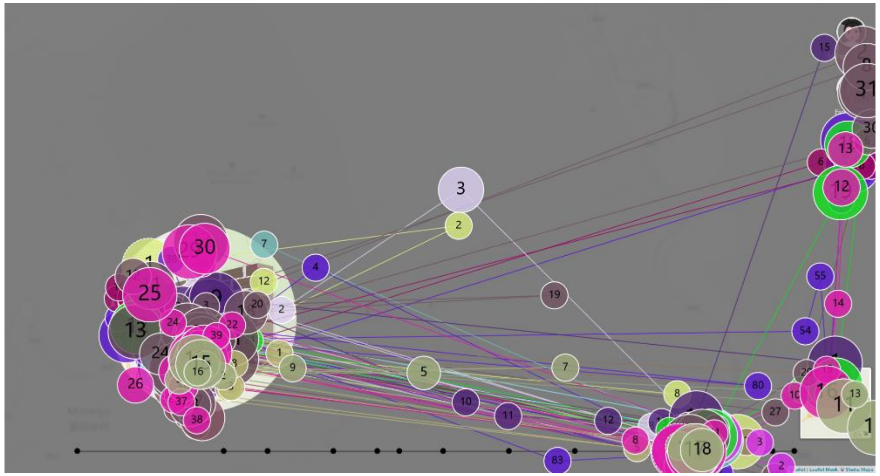

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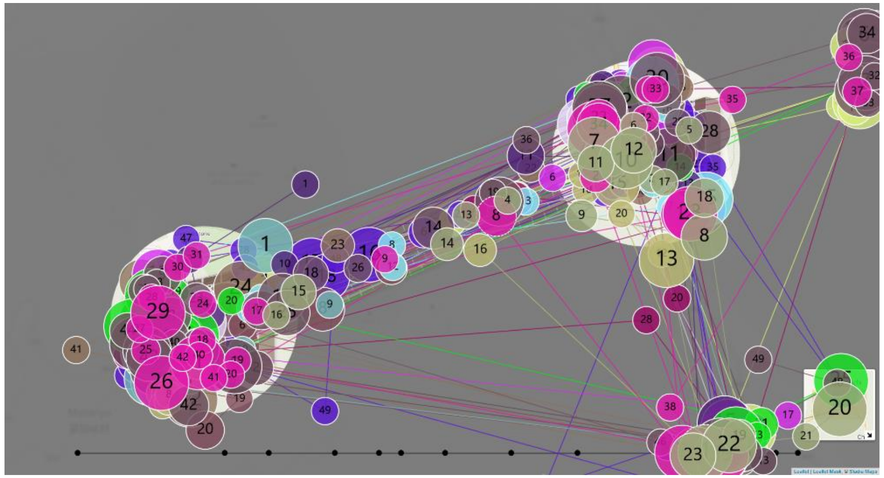
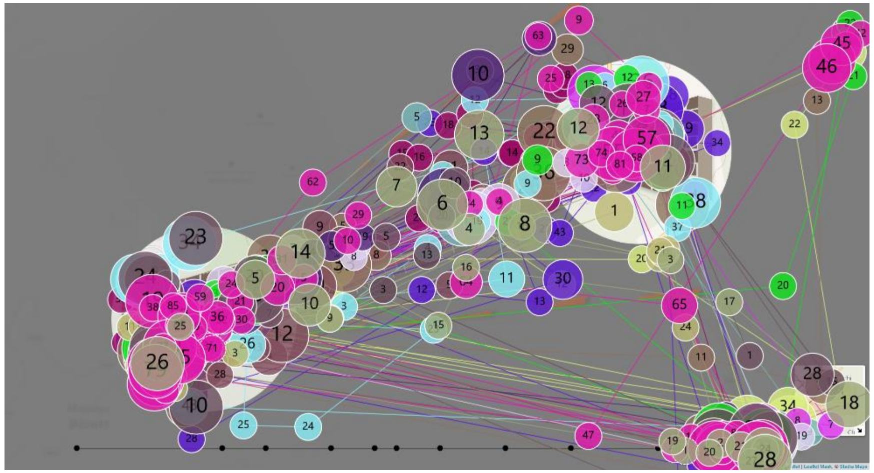

Scene 12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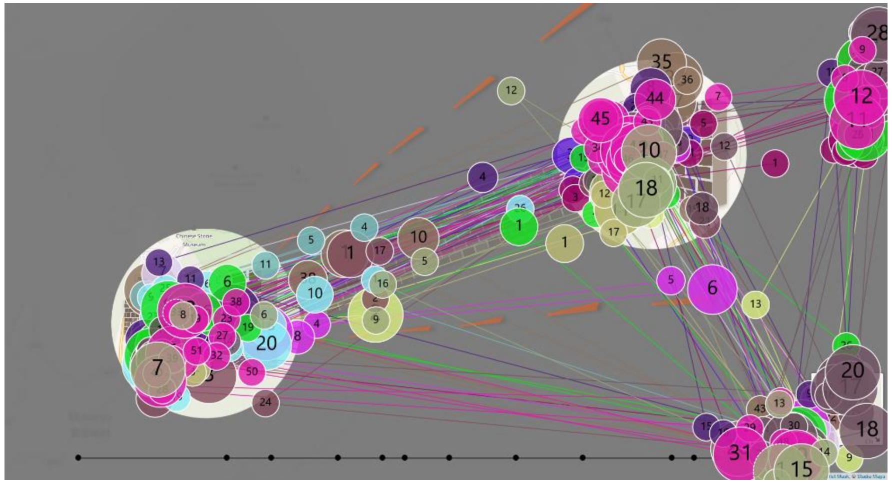
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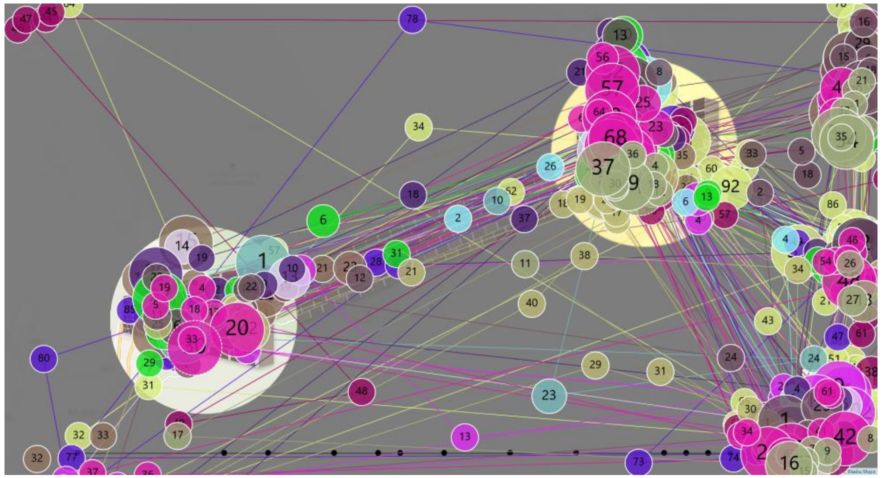
Scene 15

APPENDIX X: SAMPLE PERCEIVED STORY

TP_8 (Had no previous knowledge of the story):

There lived two individuals; Meng and Fang. These two were close, later fell in love and got married to each other. They lived happily together until Government forces arrested Fan, leaving Meng all by herself. Meng cried for her husband but to no avail. Fan was forced to work for the government forces. As time went by, Meng continued to cry day and night for the return of her husband but to no avail. With her Fan husband in mind, she decided to go visit her long lost at the distant location. Unknown to her Fan was already dead by then. On arrival at the construction place, she was informed by the government that Fan the love of her life was no more. She wept for her lost love. Her cry echoed through the walls. The skeletal remains of Fan buried in the wall heard the cry of Meng. Meng later joined her long lost love at the end.

TP_14 (Had previous knowledge of the story):

Once opon the time there was a lady named Meng Jiangnu. Her husband, Fan, and her got married and had a happy life. One day the government force came and asked Fan to build the Great Wall as a labourer. Meng was sad and waited for a long time, but her husband did not came back. So she went to find him, and the force told her that her husband was dead and buried in the Great Wall. Meng listened and cried till the Great Wall collapsed. Finally she found her husband's bone.

APPENDIX XI: EYE-TRACKING SET-UP

Tobii Pro Fusion screen-based eye-tracker. (Source: tobiipro.com)

The table below shows the Tobii Pro minimum system requirements versus the system used for the experiments.

Property	Required Specification	Used System Specification
CPU	Intel Core i5 3.0 GHz, quad-core	Intel® Core™ i5-8350U CPU @ 1.70GHz 1.90GHz
RAM	16 GB	8.00 GB (7.58 GB usable)
Hard disk	SSD – 256 GB or more	500 GB (280 GB available for research)
Graphics card	Dedicated Nvidia card	Intel UHD Graphics Card
Monitor	1920 x 1080 resolution	DVI, HDMI or DisplayPort connector
Operating system	Windows 10 64-bit – Professional or Enterprise versions only	Windows 10 64-bit – Home edition
Connectors	USB Type-C USB Type-C to USB Type-A adapter	USB Type-C & USB Type-B

APPENDIX XII: EYE MOVEMENT PROCESSING

Tobii I-VT (Fixation) parameters used in generating the heat maps.

Name	Tobii I-VT (Fixation)
Eye Selection	Average
Noise reduction	Moving median
Window size (samples)	3
Window length (ms)	20
I-VT classifier	A threshold of 30 °/sec
Merge adjustment fixations	75ms
Max angle between fixations (°)	0.5
Minimum fixation duration (ms)	60