TECHNISCHE UNIVERSITÄT WIEN

MASTERARBEIT

Narrating the route:

Route memorability in navigation instructions augmented with narrative

zur Erlangung des akademischen Grades

Master of Science

im Rahmen des Studiums

Internationales Masterstudium Cartography

eingereicht von

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Wien, 09.09.2022 _____ _____

(Unterschrift Verfasser/in) (Unterschrift Betreuer/in)

TECHNISCHE UNIVERSITÄT WIEN

MASTER THESIS

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for obtaining the academic degree

Master of Science

in the degree programme

International Master in Cartography

submitted by

Lydia Anna Scholl Youngblood
Matriculation number 12042699

completed at the Institute for Geodesy and Geoinformation from the
Faculty of Mathematics and Geoinformation at the Vienna University of Technology

Supervision
Supervisor: Univ. Prof. Dr. Dr. h.c. Georg Gartner
Reviewer: Dr.-Ing. Eva Hauthal

Vienna, 09.09.2022 _____ _____

(Signature of the author) (Signature of the supervisor)

Cartography M.Sc.

Master thesis

Narrating the route: Route memorability in navigation instructions augmented with narrative

Lydia Anna Scholl Youngblood

2022

Statement of Authorship

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

"Narrating the route: Route memorability in navigation instructions augmented with narrative"

I have fully referenced the ideas and work of others, whether published or unpublished.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

Dresden, September 8, 2022 Lydia Youngblood

Acknowledgements

First, I would like to thank Georg Gartner: for your guidance and input during the research process, for our enjoyable meetings, and for your enthusiastic support. It has been a joy to work with you. Additional thanks to Barend Köbben and Eva Hauthal for their help and review of this work. Special thanks to Juliane Cron for being a gem of a coordinator for the Cartography M.Sc. The program is strengthened by your guidance!

To all of my wonderful participants: this research would have been impossible without you. Thank you for your thoughtful input and for lovely hours spent over good conversation in the park. To Zulfa and Héctor for their wonderful pilot of my study and accommodation during my time in Vienna.

Thanks to my dear friends and family, near and far, for providing much needed breaks and love during the research period, for teaching me the power of a well-told story and for fostering my love of maps.

Finally, to Vivien, thank you for your support, giggles, and kind words during this time. You made the ups more fun and the downs more manageable. E a Marcello: grazie per il tuo sostegno, i tuoi abbracci e il tuo amore. Here's to more adventures!

Abstract

From oral histories to mnemonic devices, humans have an excellent ability to remember object sequences and their relationships inside of narratives (Baddeley, 1999). In pedestrian wayfinding, remembering landmarks and their relationships is considered key to learning routes (Denis, Mores, Gras, Gyselinck & Daniel, 2014). This is especially critical in mobile navigation, as it has been well-established that the use of GPS devices with metric turn-by-turn directions during wayfinding hinders spatial knowledge acquisition, both in the short-term and over time (Ishikawa, 2019). However, these devices are ubiquitous in our world today. In an attempt to develop alternative methods of route communication, some have found that using landmark-based route instructions facilitate the memorability of routes. In addition, instructions rich in visual imagery improve memorability of routes (Tom & Denis, 2004; Tom & Tversky, 2012). Few researchers have suggested alternatives to how landmark-based route instructions might be communicated beyond simple turn-by-turn directions. In addition, narrative as an aid to wayfinding has not yet been explored in outdoor environments.

This research aims to identify whether augmenting verbal route instructions with a narrative increases the memorability of a route. It is proposed that adding information in the form of narrative may make it easier for users to form meaningful connections between landmarks and thus, better remember a route in an urban environment. Narrative theory was applied as a framework to augment navigation instructions with a narrative about Johann Strauss. First, the key components of a narrative were identified. Then, these components were utilized to craft narrative navigation instructions. The instructions were tested against a control in an in-situ wayfinding study in Vienna (N = 18). After learning a short route (800m, 13 landmarks), participants recalled the route verbally, completed a photo-based landmark sequencing task and discussed their answers. One week later, a route recognition task and second photo-based landmark sequencing task was completed online.

Results show no significant differences between the narrative and control groups when measured using quantitative methods. However, in interviews, the narrative group often cited the narrative when sequencing photos and during verbal recall. These results suggest that incorporating narratives into route directions can be further explored, but that the phenomenon may not be well-measured using quantitative methods. This research further confirms the potential of landmark-based instructions to facilitate route memory,

contributes to the growing body of work augmenting route directions with additional information, and could encourage designers to consider other route communication methods.

Keywords: *narrative, route memorability, route communication, pedestrian wayfinding*

Contents

List of Figures

List of Tables

CHAPTER 1

Introduction

1.1 Motivation and problem statement

> A narrative is a perceived sequence of non-randomly connect events, typically involving, as the experiencing agonist, humans or quasi-humans, or other sentient beings, from whose experience we humans can 'learn' (Toolan, 2001, p. 8).

Narrative is a universal part of the human experience. From birth to death, humans are intimately involved in storytelling. Stories are one of the primary tools that help us convey information about our experiences in the world to each other. In addition, narratives have a particular power in human memory; a well-told story is easy to remember. In fact, a popular strategy for organizing complex information into memory is to incorporate that information into a narrative (Baddeley, 1999).

Narrative and cartography have a long relationship. Narrative has been discussed as a critical framework about the production of the map, which centers the cartographer as the curator and voice of a particular story (see e.g. Caquard & Cartwright, 2014). Narrative has also been used in cartographic design to help communicate information, as both a visual design framework (e.g. Roth, 2021) and as an extra data layer in the mapmaking process (e.g. Westerveld & Knowles, 2021). Narratives themselves have also been strengthened by cartographic products, from maps to supplement a text (whether fictional or factual), to narratives triggered by user position (Caquard & Cartwright, 2014; Greenspan, 2011; Roth, 2021). Incorporating narratives into maps is not new, however, narratives have not yet been employed explicitly as a potential memory device in cartography, nor have they been used to augment maps in the context of outdoor navigation. This is an interesting research gap, especially given the evidence against the state-of-the art of navigation aids.

Navigation is defined by Montello (2005, p. 258) as "coordinated and goal-directed movement of one's self through the environment". Navigation consists of two actions: locomotion and wayfinding (Montello, 2005). Locomotion, or movement through space, allows humans to move towards an intended destination, while wayfinding is the "planning and decision-making part of navigation" (Gartner, Huang, Millonig, Schmidt & Ortag, 2011). While navigating, one's mental representation of the environment (cognitive map) is developed and refined as new spatial information arrives, resulting in a continuously updated model of spatial features, called spatial knowledge acquisition (Lynch, 1960; Vanclooster, de Weghe & Maeyer, 2016). This acquisition of spatial knowledge is important, as over time it allows a user to easily move from one destination to another using their own spatial knowledge.

Figure 1.1: Using a mobile map in the city. Image by the author.

Wayfinding, however, is a complex task and users do not always have existing or accurate knowledge about the environment (e.g. when in a new neighborhood). Therefore, humans often rely on wayfinding aids, such as paper maps and mobile mapping applications, the latter which have come to be used as primary wayfinding aids (see Figure 1.1) (Ishikawa, Fujiwara, Imai & Okabe, 2008; Löwen, Krukar & Schwering, 2019; Vanclooster et al., 2016). Users can input their destination, and directly follow the suggested route. In mobile mapping applications, routing information is usually presented in the form of a mobile map, with verbal navigation instructions (text or audio). In most mapping applications today, verbal information is given as an action ("turn"), a direction ("left") and a distance ("in 200 meters") (Rehrl, Häusler & Leitinger, 2010). Street names are also frequently used. This format of directions is referred to in the literature as metric turn-by-turn navigation, and was originally developed for car navigation systems

(Huang, Mathis & Weibel, 2021; Krukar, Anacta & Schwering, 2020; Rehrl et al., 2010). Pedestrians, however, have different information needs than car drivers (May, Ross, Bayer & Tarkiainen, 2003). Thus, in the last decade, there has been encouragement towards human-centered pedestrian navigation systems (Gartner et al., 2011).

In response to this gap, much research has focused on how the route is *communicated* to the user. As early as 2011, Gartner et al. (2011) noted three key points of issue with route communication in human-centered pedestrian navigation systems. First, the way state-of-the-art wayfinding applications communicate routes is highly efficient, but at great cost: mobile navigation aids are detrimental to humans' ability to remember spatial information (Ahmadpoor & Smith, 2020; Brügger, Richter & Fabrikant, 2019; Ishikawa, 2019; Ishikawa et al., 2008; Krukar et al., 2020; Löwen et al., 2019). This becomes especially important when navigation systems fail, such as when mobile phones lose battery or signal. Second is that the *type* of information pedestrians require is different from car drivers (Gartner et al., 2011). It has been well-established that communicating route directions based on landmarks, as opposed to metric information, results in better spatial knowledge acquisition for pedestrians (Denis, Michon & Tom, 2007; Klippel & Winter, 2005; Michon & Denis, 2001; Raubal & Winter, 2002; Ross, May & Thompson, 2004; Tom & Tversky, 2012). Finally, Gartner et al. (2011) found that pedestrians are able to take in more detailed information than car drivers, as they do not need to spend valuable cognitive energy on driving safely.

Given these considerations, Gartner et al. (2011) encourage the exploration of "novel interface techniques facilitating both navigation and spatial knowledge acquisition" for pedestrians. This has been taken on by some researchers in the field (e.g. Anacta, Schwering, Li & Muenzer, 2017; Huang et al., 2021; Krukar et al., 2020; Wunderlich & Gramann, 2021). Only some projects, however, have gone beyond simple landmark-based turn-by-turn directions (e.g. "turn right at the church"). However, simplicity in wayfinding directions does not always correlate to better spatial knowledge acquisition (Krukar et al., 2020). In fact, findings suggest that additional information may facilitate spatial knowledge acquisition, despite adding complexity to the instructions (Gramann, Hoepner & Karrer-Gauss, 2017; Krukar et al., 2020). The communication of route directions to support rather than hinder spatial knowledge acquisition using an additional information layer is a focus of this research.

This thesis aims to build the field of human-centered pedestrian navigation, particularly in route communication research. Broadly, it explores a new way of communicating route directions to pedestrians, with the goal of supporting incidental spatial knowledge acquisition. Specifically, the research will investigate if blending a narrative with route directions affects route memorability by acting as an additional source of information that the user can rely on when remembering the route. Additionally, the research acts as a starting point for investigating the potential of narrative in wayfinding.

1.2 Research identification

The research was conducted under the following research objective (RO):

RO. To identify whether the augmentation of verbal route instructions with a narrative can be used to increase the memorability of a route for pedestrians.

In order to address the research objective, the following research questions (RQs) will be addressed:

RQ 1. What are the fundamental components of a narrative and how can they be implemented in navigation instructions?

RQ 2. Does augmenting navigation instructions with a narrative increase the memorability of a route? This will be specifically addressed with the following sub-questions:

Shortly after navigating, as well as one week later...

RQ 2.1. is the route more accurately recalled?

RQ 2.2. is the sequence of two given landmarks better remembered?

RQ 2.3. are users more confident in their memory of landmark sequences?

This research will explore a novel way of communicating a route, and its effects on memory, contributing to the advancement of research in route communication for human-centered navigation systems. In order to narrow the scope, the research will center on route memorability as a more focused measure of spatial knowledge acquisition (see section 2.4.1). Memorability is "the quality of being easy to remember or worth remembering" (Merriam-Webster, 2022). Following Denis et al. (2014), this will be measured in this thesis by how well a route is remembered.

It is important to note that this research will not be focused on the positioning or route planning phases of navigation, but rather specifically on the communication of the route to the user. In addition, this research does not set out to explain the mechanism of *how* a user remembers a route, which is more appropriate in the field of cognitive neuroscience. Rather, it will offer an initial exploration of the potential of narrative in wayfinding instructions and to test if there are effects on memory compared to instructions without. Finally, this research will not aim to produce a new navigation application or tool, but rather to assess whether narrative could be a useful tool in building future applications better suited to the acquisition of spatial knowledge.

1.3 Structure of the thesis

This thesis is separated into five main chapters: Introduction, Theoretical Background, Methods, Results and Discussion, and Conclusion. The following chapter, Theoretical Background, discusses the background informing this work from the fields of cognitive psychology and narratology. It also addresses the first research question with a discussion of the principal components of narrative, and then outlines previous work in navigation. The chapter concludes with a discussion of examples of narrative in cartography.

The third chapter, Methods, discusses the methods undertaken during this research. First, a background of the thesis' methodological approach is given, including design of the route directions as well as the methods implemented during the user study. Next, the user study's preparation and procedure is discussed in detail. The chapter concludes with the methods used during data analysis.

Chapter 4 outlines the results of the study, presented for each phase of the user study. Analysis of these results is presented within each phase and discussed together at the end of the chapter. The thesis concludes with Chapter 5, Conclusion, where the research questions are summarized and limitations and implications for further research are discussed.

CHAPTER 2

Theoretical background

2.1 The role of narrative in cognitive psychology

From oral histories to mnemonic devices, incorporating information into a narrative is a powerful tool for memory (Baddeley, 1999; Baddeley, Eysenck & Anderson, 2015; Crowley, 2018; Reisberg, 2010). This is likely because remembering organized information is much easier for humans than remembering unorganized information (Baddeley, 1999). While it is out of the scope of this thesis to undertake an in-depth discussion of cognitive psychology, some details relating to memory are useful in situating the discussion about the potential of augmenting wayfinding instructions with a narrative.

One of the first theories to emerge regarding organization of information is the theory of "schemas" proposed in 1932 by Bartlett (Baddeley, 1999). Coming at a time where the study of memory was dominated by the study of rote learning and recall, Bartlett argued that meaning was one of "the most central and characteristic feature[s]" of human memory (p. 4, Bartlett & Kintsch, 1995, as cited in Baddeley, 1999; Baddeley et al., 2015; Negrete, 2021). He proposed that when someone hears new meaningful information, they are able to store and then later recall it because of each person has a "long-term structured representation" of knowledge previously learned about the world, or a schema, in which they can incorporate the information (Baddeley et al., 2015, p. 139; Crowley 2018).

A second aspect that may also play a role in contributing to narratives' power as memory devices is our ability to organize incoming information visually. Objects that are imagined interacting are much more likely to be successfully recalled when prompted than objects that are not imagined at all, or even imagined simply side by side (Baddeley, 1999; Reisberg, 2010). Furthermore, the more odd, interesting, or vivid the situation is, the more likely it is to be remembered, though only if in contrast to other, less odd, situations (Wollen, Weber & Lowry, 1972, as cited in Reisberg, 2010). Providing a narration with

vivid visual imagery could help the user create meaningful, visually engaging memories of the route. Interestingly, the concept of vividness has been tested in Tom and Tversky (2012). Building off of Tom and Denis (2004), who found that landmarks are better remembered than streets when they are described vividly, Tom and Tversky (2012) found that routes with vivid landmarks or street names were remembered much better than routes with less vivid streets and landmarks. Participants recalled more streets and landmarks and were more correct in placing them on a map when they received a vivid instead of a basic description.

The existing research is clear that organizing information into a narrative has a positive effect on memory compared with listed or otherwise unorganized information (Baddeley et al., 2015; Crowley, 2018; Reisberg, 2010). Existing schemas may allow people to organize new information into a pre-existing hierarchy, relating new information to previously learned information in their own way. The more meaningful detail given to the new information, the easier it is to related it in a schema (Bartlett & Kintsch, 1995, as cited in Baddeley et al., 2015; Crowley, 2018). Visual imagery may help invoke stronger memories of narratives as we imagine real or fictional situations. Incorporating navigation instructions into a narrative might provide more avenues for a user to connect with the physical world through their own already existing schemas, and increase the visual imagery of the instructions, further aiding memory.

In the field of cognitive psychology, the terms story and narrative are used interchangeably. In narratology however, there is a very clear distinction between the story, or the raw events that occurred, and the narrative, the telling of these events. In order to create a set of wayfinding instructions incorporating a narrative, definitions of narrative are analyzed to determine the main components required to craft a narrative. This follows Herman (2002), who sees narrative not only "as a discourse genre and cognitive style," but also as a "resource for writing" (p. 1, as cited in Doloughan, 2011).

2.2 Defining narrative

In order to further breakdown the fundamental elements of narrative, properly defining the term is necessary, though it is no easy task. As Roth (2021, p. 84) describes, narration and storytelling are so "fundamental to the human experience that the terms are often not defined in the literature." In cartography, the term is often used synonymously with "story," but in narratology, the terms are distinct. This thesis will follow the definitions of the terms from narratology, as separating them is useful as a guide to writing a narrative. The following section outlines the historical and modern definitions of the term and the resulting fundamental components included in many definitions. These components are then used in Section 3.1.1 to craft a set of narrative navigation instructions.

2.2.1 Historical framework

In narratology, whole book sections or chapters are devoted to the topic of defining narrative (e.g. "Defining narrative," Ryan (2005) and "Towards a definition of narrative" Ryan (2007)). There are, however, some central tenets in the field on which many of these definitions are built. Many of these arise from a classical narratological approach.

Much of the seminal work in classical narratology occurred during the second half of the 20th century, with authors such as Seymour Chatman, Roland Barthes, Vladimir Propp, leading the way, to name a few Toolan (2001). In this period, fewer specific definitions exist, and the focus was more on breaking down the characteristics of what makes a narrative a narrative. While some of this work is considered especially reductionist (e.g. Propp's famous characterization of Russian fairy tales), it laid the groundwork for further scholars to define the field of narratology (Chatman, 1978; Herman, Jahn & Ryan, 2005; Toolan, 2001).

Within this work, and stretching to more modern attempts at defining narrative, there is broad agreement on the dualistic nature of narrative, that it consists of two principal parts (there are a few exceptions, see e.g. Bal, 1985, as cited in p. 12 of Toolan, 2001). These two parts can be considered the *what* and the *way* of a narrative (Abbot, 2007; Chatman, 1978; Herman et al., 2005; Toolan, 2001). The *what* of narrative is often referred to in English as "story" (French: "historie," Russian: "fabula"), and the *way* as "discourse" (French: "discours," Russian: "sjuzhet") (Chatman, 1978; Herman et al., 2005; Toolan, 2001).[1]

Story is often further broken down into *events* (actions and happenings) and *existents* (characters and setting); it is the "basic unshaped story material" (Chatman, 1978; Herman et al., 2005; Toolan, 2001, p. 15). Chatman (1978, p. 37) notes that story on it's own is an abstract representation; any attempt to tell the story "already entails the selection and arrangement performed by the discourse." Without the telling, through dance, text, speech, etc., the events and existents do not exist.

Bringing the raw story material into the world then requires the discourse. Discourse refers to "the means through which the story is transmitted" and deals with how the events that occurred are conveyed to the consumer of a narrative (Chatman, 1978, p. 9). It can also be thought of as a 'version' of the story: each teller of the story will create a different narrative via their use of discourse (Toolan, 2001). This is key because it allows different mediums to become narrative: a painting or dance, for example, can transmit a story Chatman (1978); Ryan (2005). As Ryan (2005) points out, not all mediums have equal narrative potential. This is perhaps why much of classical theory in narratology primarily focuses on text and literary works. The discourse includes not only the medium that is used to transmit the story elements (the *how*), but also the *manner* in which they are transmitted.

[1] The terms differ slightly and are rough equivalents (Toolan, 2001). For more information about the distinction, Herman et al. (2005) is a good starting point.

While there seems to be general agreement on what makes up the story of a narrative, what the discourse must consist of is less clear Abbot (2007). For this, it is useful to turn to more recent attempts to summarize narrative into a coherent definition to aid construction of narrative instructions.

2.2.2 Modern definitions

Recently, scholars have built upon this dualism and attempted to develop a coherent definition of narrative. Toolan (2001)'s definition quoted in the introduction of this work is an oft cited one-sentence example:

> A narrative is a perceived sequence of non-randomly connect events, typically involving, as the experiencing agonist, humans or quasi-humans, or other sentient beings, from whose experience we humans can 'learn' (p. 8).

Toolan (2001) further summarizes the three defining features of narrative in his own definition as: sequenced or interrelated events, foregrounded individuals, and crisis to resolution progression (as the frequently preferred sequence of events).

Similar to Toolan (2001), Ryan (2005) defines narrative as follows, adding that the mental states and events are important as well. They additionally incorporate space:

- Narrative involves the construction of the mental image of a world populated with individuated agents (characters) and objects (spatial dimension).
- This world must undergo not fully predictable changes of state that are caused by non-habitual physical events: either accidents (happenings) or deliberate actions by intelligent agents (temporal dimension).
- In addition to being linked to physical states by causal relations, the physical events must be associated with mental states and events (goals, plans, emotions). This network of connections gives events coherence, motivation, closure, and intelligibility and turns them into a plot (logical, mental, formal dimension) (Ryan, 2005, p. 4).

The Routledge Encyclopedia of Narrative Theory also presents this definition, but additionally notes that some stories may become narratives, while some may only "posess narrativity" (Herman et al., 2005, p. 347). Both Chatman (1978)and Ryan (2005) also argue that narratives can posses different degrees of narrativity, or the amount that they incorporate the different fundamental elements of narrative, and some may focus more one one or another element. Partially to address this, Ryan (2007, p. 29) later proposes that instead of an explicit definition, narratology benefits from a "fuzzy-set" definition of narrative; namely one that "allows variable degrees of membership, but [is] centered on prototypical cases that everybody recognizes as stories." To Ryan (2005, p. 29), a definition should consider:

1. Narrative must be about a world populated by individual existents.
2. This world must be situated in time and undergo significant transformations.
3. The transformations must be caused by non-habitual physical events.
4. Some of the participants in the events must be intelligent agents who have a mental life and react emotionally to the states of the world.
5. Some of the events must be purposeful actions by these agents.
6. The sequence of events must form a unified causal chain and lead to closure.
7. The occurrence of at least some of the events must be asserted as fact for the story world.
8. The story must communicate something meaningful to the audience.

This "fuzzy-set" definition of fundamental elements of narrative allows for greater flexibility in which works are considered narratives (better incorporating works such as painting, performance art, sculpture, etc.), while excluding categorically non-narrative pieces (such as weather reports) Ryan (2005, 2007). It also allows for certain works to be 'more narrative' in regards to some parts of the fuzzy definition, and 'less narrative' in others.

2.3 Fundamental components of narrative

Taking the above modern and historical definitions, a summary of essential components of narrative can be generated. Overall, narratives are raw story material (story) coupled with the telling of said story (discourse). One key part of the story material is the existents, consisting of characters and setting. Characters must be individuated (Ryan, 2005, 2007) or sentient (Toolan, 2001). Setting is the "place and collection of objects against which [a character's] actions and passions...emerge" (Chatman, 1978, p. 138). This can be a place, but it can also be objects that contribute to the overall mood of the narrative (Chatman, 1978). Figure 2.1 diagrams the fundamental components of narrative.

The second key part of story is the events. These are actions (things that characters do) and happenings (things that happen to them) (Chatman, 1978), some of which must be purposeful (Ryan, 2007), and should not be fully predictable (Ryan, 2005). These events should be connected non-randomly (Chatman, 1978; Toolan, 2001), or "form a unified causal chain and lead to closure" (Ryan, 2007, p. 29).

In the discourse of the narrative, these events should be ordered in some way by the author. It is this order that then effects the causal links of the events Chatman (1978). Both Ryan (2005, 2007)'s and Toolan (2001)'s definitions include sequence; that the selected order of events matters to the overall narrative. In *The Cambridge companion*

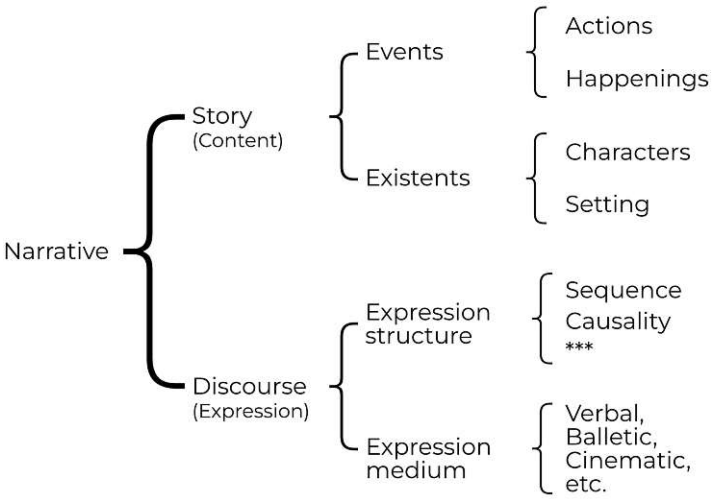


Figure 2.1: The two main components of narrative, story and discourse, are broken down further into events and existents, and expression medium and structure. The asterisks denote that sequence and causality are not the only two considerations for the writer of a narrative, but were identified in this research as the most central. Figure adapted from Chatman (1978) with data from Abbot (2007); Bridgeman (2007); Ryan (2005, 2007); Toolan (2001).

to narrative Bridgeman (2007, p. 57) adds, "the order in which events are presented in the text is...crucial to our temporal experience of narrative." Talking about events that happened in the past can lend background information to characters and setting, allowing new information to be revealed about the story (Bridgeman, 2007). Flashing forward, on the other hand, can generate suspense or brief anticipation, useful tools for keeping readers engaged (Bridgeman, 2007). Finally, the order in which the audience receives the story events can completely change the outcome of the narrative.

The order of events in turn effects the causal relationships of the events. Causality is a central requirement for narrative, dating back to Aristotle (Chatman, 1978). A classic example of causality is from E.M. Forster:

1. The king died and then the queen died.
2. The king died and then the queen died of grief (Forster, 1927, as adapted by Chatman, 1978).

Chatman (1978) argues that the first sentence is simply a report, while the second is a narrative, because of the causal connection between the deaths. This causality is not always explicit. Human minds "inveterately seek structure:" if two seemingly non-related events are presented, we will automatically assume they have a relationship with the overall structure of the narrative (Chatman, 1978, p. 45). In this way, the first sentence example above can also be considered a narrative, although the causal relationship is much weaker. Additionally, Ryan (2005)'s definition posits that the causal relations are

built not only between events but also between events and the mental reactions of the characters. This in turn creates a "network of connections" and makes the narrative understandable (Ryan, 2005, p. 4).

Finally, while it may seem obvious, the narrative must be expressed in some way. This is implied in both Toolan's and Ryan's 2007 definition: narratives "must communicate something meaningful to the audience" (Ryan, 2007, p. 29), "from whose experience we humans can 'learn"' (Toolan, 2001, p. 8) Ryan (2005) does not include audience or expression in their definition, but continues with an extensive discussion of medium and mode of narrative expression (see e.g. p. 9-21). The way a narrative can be expressed is diverse, though Ryan (2005) notes that some modes of expression lend themselves to narrative more easily, with text being the easiest.

In summary, it is possible to identify the primary components to include in developing a narrative from the literature. From the research above, it was determined that a narrative should consist of existents, including characters in a setting, and of events, including actions that the characters take and happenings that occur to them that result in a transformation and that are not predictable. These events must be causally related and purposefully sequenced, and expressed in some way. Section 3.1.1 details the design of narrative instructions for this research, while the following section outlines related work in the field of navigation.

2.4 Related work in navigation

In order to situate the use of narrative as a potential wayfinding tool, an overview of related studies and research directions in navigation is necessary. This work draws from previous studies on spatial knowledge acquisition, pedestrian wayfinding, landmark-based navigation, and route communication.

2.4.1 Spatial knowledge acquisition

Few researchers have specifically study route memorability, tending more to look at spatial knowledge acquisition as a whole, mixing methods to study the acquisition of landmark, route, and survey knowledge together. One exception is Denis et al. (2014), building off the research of Tom and Tversky (2012), who found that descriptively-named streets and landmarks were more likely to be remembered. Denis et al. (2014) found that routes are more easily remembered when the environment is visually rich. In order to narrow the scope of this master's thesis, route memorability was chosen as the study focus, incorporating methods which measure route knowledge from studies which blend methods to study overall spatial knowledge acquisition. For this reason, a discussion of spatial knowledge acquisition is necessary. This section breaks down what spatial knowledge is and how it is acquired, and then discusses select studies that have attempted to improve acquisition during wayfinding.

Various theories exist regarding how humans encode spatial information into their cognitive map. As cited in Kim and Bock (2021), Siegel and White (1975)'s influential theory posits that overall spatial knowledge acquisition occurs in three separate: landmark knowledge, route knowledge, and survey knowledge. Landmark knowledge is knowledge about discrete attributes of an object or scene in the environment (Ishikawa & Montello, 2006). These attributes are referred to as salience, the property that makes a landmark distinct from its surroundings. Landmarks may be visually (e.g. the yellow buildings shown in Figure 2.2), cognitively (e.g. post office), or structurally salient (e.g. a park in a prominent, accessible location in the environment) (Yesiltepe, Dalton & Torun, 2021). Route knowledge is the sequence of landmarks and direction choices that must be made to reach a destination. Survey knowledge is seen as the most complex level of spatial knowledge acquisition, and is an overall internal representation of the environment, a map-like representation which is properly scaled and allows for shortcuts and new routes (Ishikawa & Montello, 2006; Kim & Bock, 2021).

Figure 2.2: A view along the tree-lined street from the user study. Image by the author.

It was originally posited that when navigating in a new environment, a user first acquired landmark, then route, and finally survey knowledge (Siegel & White, 1975, as cited in Ishikawa & Montello, 2006). More recent studies, however, have indicated that these knowledge types may be acquired in parallel (Ishikawa & Montello, 2006; Kim & Bock, 2021). Regardless of the order of acquisition, it is recognized that there is some overlap amongst the stages. When recalling a route, people often refer to landmarks that they remember along the way, indicating the importance of landmarks as reference points in the environment (Daniel et al., 2007; Denis et al., 2007, 2014; Tom & Denis, 2004). This overlap is also important to note, as many methods in the literature that assess route knowledge include landmark knowledge (see Section 3.1.5).

Given the wealth of research that have shown that current digital wayfinding aids are detrimental to spatial knowledge acquisition, researchers have tested various alternatives.

Much of this work has been in the context of pedestrian navigation, which will be the focus of the following sections.

2.4.2 Pedestrian needs in wayfinding applications

While state-of-the-art navigation applications still employ methods designed for car navigation systems, research has increased in the last decade on how to better design navigation systems for the needs of pedestrians (Brügger et al., 2019; Gartner et al., 2011; Huang et al., 2021; Krukar et al., 2020; Rehrl et al., 2010). This work aims to contribute to this research direction.

It is well documented that pedestrian needs for wayfinding are different than those for car drivers (Anacta et al., 2017; Gartner et al., 2011; May et al., 2003; Rehrl et al., 2010). For one, pedestrians move at slower speeds and spend less cognitive energy focused on driving, allowing increased intake of information (Millonig & Schechtner, 2007).

A second difference for pedestrians is that they need not be constrained by networks such as roads or even paths. Vanclooster et al. (2016) presents an overview of current models allowing pedestrians to seamlessly navigate between indoor and outdoor environments. Huang et al. (2021)'s work show it is feasible to allow users to wander their own route within a potential route area.

A third consideration in pedestrian navigation, and the most studied, is that pedestrians prefer to use "environmental information (such as landmarks) and do not rely much on metric information" (Michon & Denis, 2001; Rehrl, Leitinger, Gartner & Ortag, 2009, as cited in Gartner et al., 2011). As Krukar et al. (2020, p. 4) notes, "metric turn-by-turn information is a very challenging stimuli to learn: it is numeric, abstract, difficult to visualize, and similar to each other." Much of the research in human-centered navigation has focused on the *type* of information conveyed and its effect on spatial knowledge acquisition.

2.4.3 Landmark-based navigation

In response to the findings in the last decades that GPS-based navigation leads to poorer spatial knowledge acquisition, many scholars have offered solutions to adapt mobile tools to increase the spatial knowledge acquired when using them. The most prominent finding is the influence of landmarks on the acquisition of spatial knowledge. Landmarks are of critical importance to wayfinding; they act as anchors in the landscape, both globally and locally (Denis et al., 2007; Görling & Golledge, 2018; Lynch, 1960; Wunderlich & Gramann, 2021), and are relied upon to connect parts of a route (Denis et al., 2014).

Michon and Denis (2001) found that verbal route descriptions by users tended to include many references to landmarks, especially at points where an action must take place, or in moments of uncertainty (multiple options possible). Further research by Raubal and Winter (2002) proposed enriching route directions with local (on-route) landmarks, and developed an automatic extraction method to choose landmarks that should be

incorporated into directions along a route. Tom and Denis (2004) found that memory for routes was better when participants received route information referring to landmarks instead of referring to streets. In a follow-up study discussed in Section 2.1 however, Tom and Tversky (2012) found that better memory was more related whether the names of streets or landmarks were high in mental imagery than whether a street versus landmark was used in the directions. This study suggests that it may not necessarily be that the landmark is more memorable, but that landmarks inherently provide more description than street names.

Wunderlich and Gramann (2021) found in multiple experiments that navigators had improved landmark and route knowledge when using landmark-based navigation instructions compared to metric instructions, while Löwen et al. (2019) found that incorporation of local landmarks supported users' acquisition of route knowledge, while global landmarks supported users' acquisition of survey knowledge. Wang and Ishikawa (2018) found that landmark-based navigation instructions were especially helpful for people with a poor sense of direction (SOD).

The literature also indicates that user satisfaction is higher when using landmark-based navigation. Ross et al. (2004) found early on that enhanced instructions including landmarks had a positive impact on navigation efficiency and user satisfaction. Rehrl et al. (2010) compared voice instructions enhanced with landmarks to metric directions and found that while performance was similar between the two, user confidence was significantly higher in the group navigating with landmark-enhanced directions. Taken together, these studies indicate that even if some types of landmark-based instructions do not improve performance, the increase in spatial knowledge acquisition as well as user comfort is an important contribution towards human-centered navigation systems.

2.4.4 Beyond simple landmark-based instructions

Furthering the development of route directions to facilitate spatial knowledge acquisition, some recent research has investigated how additional information can be layered on top of basic route directions. For example, Gramann et al. (2017) found that providing personal and impersonal facts about landmarks at decision points decreased navigation errors, increased the number of landmarks remembered, and improved sketch maps when compared with standard navigation instructions. Furthermore, the additional information did not increase cognitive load (Gramann et al., 2017). However, the standard navigation instructions did not mention landmarks, while the augmented instructions did.

In an attempt to investigate whether survey and route knowledge could be communicated simultaneously to the user, Krukar et al. (2020) studied differences between turn-by-turn, "spatial chunking," and "orientation" instructions, also incorporating landmarks. Spatial chunking, proposed by Klippel, Tappe and Habel (2002), is where instructions are broken down into "cognitive chunks," or comprehensible pieces that mimic how humans communicate (e.g. "go through the park"), and do not necessarily mention every decision point (Krukar et al., 2020). The orientation instructions, designed by Anacta

et al. (2017), included survey-level information, in addition to route information (e.g. "go around the city center towards the church, then go through the park" Krukar et al., 2020). Importantly, results indicated that even though augmenting landmark-based instructions with additional information increased the length and complexity of navigation instructions, the information significantly improved pedestrians' acquisition of survey knowledge without affecting acquisition of route knowledge (Krukar et al., 2020). They further conclude that their more-complex orientation instructions provided more meaning to the users, facilitating their memory (Krukar et al., 2020).

Importantly, these studies provided extra information to the user within the directions, increasing the complexity of the directions in addition to increasing acquired spatial knowledge. They demonstrate that some additional information may give the user more opportunity to derive meaning out of the instructions, thus making them more memorable (Krukar et al., 2020). These findings not only support Gartner et al. (2011)'s suggestion that pedestrians have the ability to take in more detailed information, but also that this additional information can be beneficial in supporting environmental learning.

2.4.5 Auditory route communication

While some have studied what *type* of information is communicated in the route, others have studied the *mode* of communication. Route communication can be visual (e.g. a map), tactile, verbal (text or voice), or a combination thereof, and studies show that these modes can affect how the user acquires spatial knowledge (Rehrl et al., 2010). One major challenge in communicating route directions is to hold the attention of the user just enough that they accomplish their goal of navigating, but not so much that they do not pay attention to their environment (Brügger et al., 2019). One way designers have attempted to accomplish this is by testing navigation with voice-only instructions, eliminating the distracting screen of a device. Voice instructions are used in this study for the same reason, so previous work is important to this research.

On the one hand, both Huang, Schmidt and Gartner (2012) and Münzer, Zimmer, Schwalm, Baus and Aslan (2006) found that participants performed poorly when navigating with voice instructions in a navigation system, suggesting the poor results are due to the lack of active encoding during the wayfinding task; the user is passively observing or being told the route (Huang et al., 2012). On the other hand, many recent studies with similar degrees of passivity have found that voice instructions can be used successfully.

In multiple studies Wunderlich and Gramann (2021) and Wunderlich, Grieger and Gramann (2022) found that auditory-only instructions could be used successfully. These experiments used auditory navigation to test the effects of route directions enhanced with semantic information on intersections. Krukar et al. (2020) also found auditory instructions useful for navigating routes, with the auditory mode outperforming the visual mode used in their study on orientation instructions (see above). Importantly, all of these studies used landmarks in the navigation instructions.

Finally, Rehrl et al. (2010) found that landmark-enhanced voice instructions increased user confidence, though the performance was similar to voice instructions with metric information. The researchers confirm the suggestion by Streeter, Vitello and Wonsiewicz (1985), that when crafted with care, audio-based navigation instructions can be successful. Taken all together, the studies suggest that verbal instructions are easily understood and implemented by users, but more so when the instructions are landmark based and carefully designed.

While initially mixed, recent research has found that auditory route communication can be successfully implemented, and in some cases is beneficial to the user's acquisition of spatial knowledge or confidence. In addition, researchers have established the prowess of landmark-based navigation systems to communicate a route to a user. Furthermore, some have found that layering additional information onto the instructions can increase the route knowledge acquired while navigating, despite increasing complexity. One avenue yet unexplored is weaving a narrative into the directions to increase memorability.

2.5 Augmenting maps with narrative

While incorporating a narrative into mobile navigation aids for outdoor use is novel, narrative itself is not new to cartography. This is not surprising, given that place, described by Pearce (2008) as "space shaped by experience" and narrative are closely related. Narrative setting, where story events occur, is a fundamental component of narrative; descriptions of place in narrative are so essential to the narrative that a new world is built, the story world (Herman, 2010). Narrative and cartography have supported each other in different ways. Narratives have been augmented by a user's location (e.g. locative-fiction (e.g. Paay et al., 2008) or in museum narratives (e.g. Wolff, Mulholland & Collins, 2013) Narratives have been strengthened and supported by maps (e.g. Indigenous histories or maps of fictional worlds) (Roth, 2021). Cartographers have also used narrative as a framework for visual design (e.g. Roth, 2021), as well as a way to analyze the process of mapmaking itself (Caquard & Cartwright, 2014). Finally, narrative has been used to augment maps as an additional source of data. This final case is of particular interest to this research.

Regarding augmenting maps with narratives, the work of Pearce is particularly interesting. Pearce (2008) argues that narrative provides an additional opportunity to convey a sense of place in maps. In their map *The Inticacy of These Turns and Windings: A Voyageur's Map*, Pearce (2008) incorporates text excerpts from the diary of a young clerk traveling by canoe to lend voice to the journey. The author applies the visual variable of hue to convey the mood of the clerk's narrative, framing to segment the map by time as relayed in the narrative, and a small scale to bring the reader into the narrative (literally, physically close to the map on the wall) (Pearce, 2008). Text from the narrative then accompanies each frame of the map.

Pearce and Hermann (2010) augment their map *They Would Not Take Me There; People, Places, and Stories from Champlain's Travels in Canada, 1603–1016* (Figure 2.3)

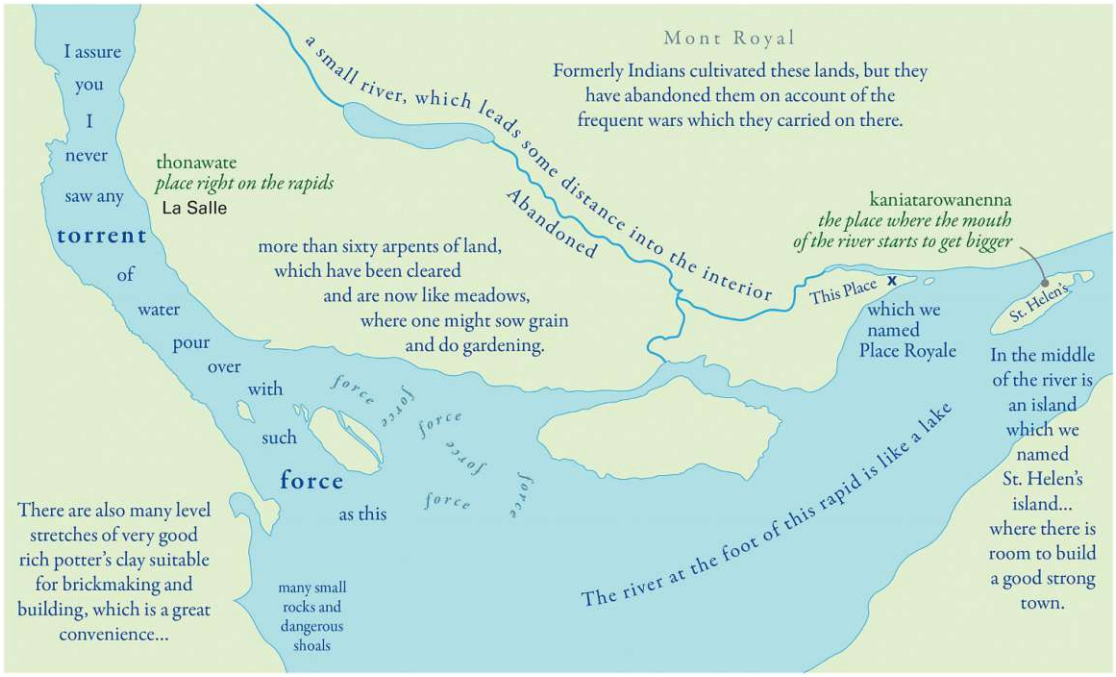


Figure 2.3: Pearce and Hermann (2010)'s map *They Would Not Take Me There; People, Places, and Stories from Champlain's Travels in Canada, 1603–1616*, published by the University of Maine Canadian-American Center. Words from Champlain's narrative are shown in blue, while words from a fictional narrative by Indigenous people from the area imagined by the authors are shown in green. Map by Pearce and Hermann (2010), image from Roth (2021) used with permission from the University of Maine Canadian-American Center.

with multiple narratives. They incorporate both words written by Champlain himself, using the words to describe the landscape and the journey (blue Garamond). They also include an imagined narrative from Indigenous people of the region to avoid the voicelessness of Indigenous people that so many maps of the journey perpetuate (green Garamond) (Pearce & Hermann, 2010; Roth, 2021). Here, narrative gives the map reader additional information that encourages a deeper understanding of place and context than a traditional historical route map (where "specific route locations for a historical figure [where was he, when?]" are the goal) (Pearce & Hermann, 2010, p. 34). In this way, the narrative acts as a primary data layer for the map.

Another example of a narratives being incorporated into a map is in Westerveld and Knowles (2021)'s map *I was there*. Similar to Pearce (2008), Westerveld and Knowles (2021) develops a visual representation of the narratives of two holocaust survivors, Anna Patipa and Jacob Brodman. The authors develop the map to visually represent the places discussed in their narratives. The visual design of the map is influenced by the narrative and the text is then incorporated into the final product. Different places are represented across scales, from known geographic locations, plotted with Cartesian coordinates, to personal spaces, such as "grammar school," placed topologically related to nearby places

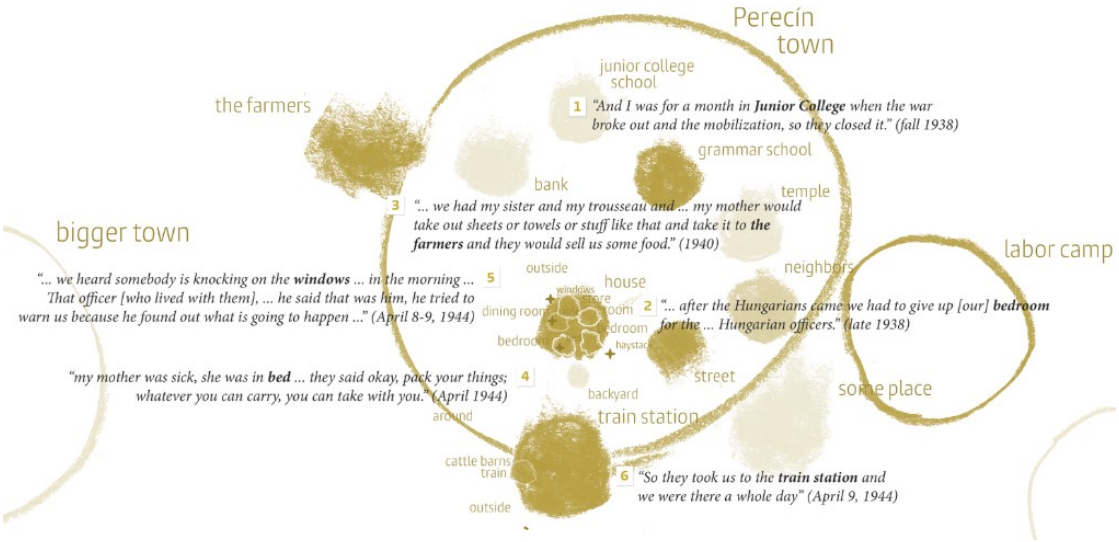


Figure 2.4: An excerpt of Westerveld and Knowles (2021)'s map *"I was there."*. To map the narratives of two survivors of the Holocaust, authors related the places mentioned topologically, adding text excerpts of the narratives. Map by Westerveld and Knowles (2021).

(Westerveld & Knowles, 2021). Figure 2.4 shows an excerpt of the map.

In all three of these maps, excerpts from narrative(s) are used to develop the map. This, in turn, gives more meaning to the information conveyed. Narrative is used as both a primary data source and as a visualization tool to convey meaning. These three maps are just a snapshot of how narratives have been layered with other data to deepen the understanding of a spatial phenomenon in cartography. This manner of layering narrative into maps has not yet been explored as a method of route communication in outdoor wayfinding, which is of interest given the impact narrative can have on an audience's sense of place and memory (Baddeley, 1999; Crowley, 2018; Pearce, 2008). The following chapters will outline how a narrative was incorporated into landmark-based route directions and the results on memorability of the route.

CHAPTER 3

Methods

To test the memorability of narrative-based instructions, participants were recruited for an in-situ wayfinding study in the city of Vienna. Two sets of route instructions were designed, one containing directions augmented with a narrative ("narrative instructions") and a control set with the same landmarks as mentioned in the narrative instructions ("landmark instructions"). This chapter first explains the methodological approaches adopted for the design of the route directions and for each phase in the user study (Section 3.1). In the next section (3.2), the details of the user study, including route selection, participants and procedures are discussed. Finally the methods used to analyze the resulting data are discussed in Section 3.3. Throughout the research, the terms "participant" and "user" are used interchangeably.

3.1 Methodological approach

3.1.1 Design of route directions

While designing narrative instructions for wayfinding, two primary requirements were kept in mind. The first was that the instructions are augmented by a narrative that contained the identified foundational elements of narrative determined in Section 2.2. The narrative should consist of existents, including characters in a setting, and of events, including actions that the characters take and happenings that occur to them that result in a transformation and that are not predictable. These events must be causally related and purposefully sequenced. The second consideration was that the narrative instructions are ultimately navigation instructions: designed to help a user from one point to another. The following section will briefly break down the two main design requirements. The resulting route directions can be seen in Table 3.1. An overview map of the route in Figure 3.1 is shown for reference.

Augmented by narrative

It was noted during research that state-of-the-art wayfinding instructions already share some characteristics of narrative. Most clear are actions, sequence, and setting. Directions are actions: they provoke movement with a purpose. These actions are ordered: mixing the order of the directions completely changes the outcome of the navigation. Wayfinding takes place in a certain setting: the information the user receives is directly related to the physical location they are navigating. Additionally, the directions must be communicated in some way to the user, and the mode of this communication can vary.

Weaker in wayfinding instructions, however, is explicit causal relationships between the actions and explicit existence of a character (and their transformation).[1] The existence of these similarities and differences between narrative and route directions acted as a focus point for designing the narrative instructions. For this reason, route directions in this research were augmented with a narrative of connected story events which take place at specific landmarks along the route. This ensured not only the presence of causal links, a primary component of narrative, but also that the physical environment was connected to the story environment, blending the narrative with the directions. It is here in the connections of events to each other, and their connections in turn to the physical world, that narrative could provide a useful tool for memory of a route (Baddeley, 1999; Reisberg, 2010).

Furthermore, providing a user additional information that they can already relate into their own existing 'schema' could help them relate to the information, more so perhaps, if the narrative provides vivid mental imagery along the route. (see Section 2.1). Therefore, the main focus of designing the narrative instructions was to provide strong causal relationships between each event in the narrative world, using concepts or imagery that was as vivid as possible. This in turn incorporated characters (Johann Strauss, his dog, his wife, the resident who through the roses, the fighting table tennis players, the voters and protesters), into the narrative world, strengthening the overall narrative, although the addition of characters was not the main focus.

An example of this causal linking can be seen in the fourth and sixth directions. In the fourth direction, Strauss decides to visit the oldest public toilet in Vienna. He then remembers a previous protest of the toilet's construction in the sixth direction. The two events rely on each other for context and intelligibility and provide additional information about the character and setting. Additionally, the sixth direction is visually evocative, with a resident throwing "dozens of pink roses from the balcony in protest."

[1] A weak causal relationship might be said to exist: turning onto "Bridge street" might be impossible without first crossing the bridge, for example, but this seems a stretch. Additionally, the user could be considered a character, but there is no guarantee of transformation, nor is navigating a non-habitual event.

Route directions designed for the study

	Landmark	Narrative
1.	Exiting the *palace*, turn left.	Johann Strauss needed to take his dog to the veterinarian. He left his white *palace* and turned left down the street.
2.	Turn left at the *furniture restoration shop*.	By the time he got to the *furniture restoration shop* on the corner, his old body was tired, and he wished for a rest in one of their chairs. But he turned left and continued up the street.
3.	Walk past the *purple door*.	He smiled as he passed the *purple door* where he had met his wife 30 years ago.
4.	Turn right at the *sign for the toilet*.	At this age, he couldn't make it far without a toilet, so he took a right at the *sign for the toilet*, the oldest public toilet in Vienna.
5.	Turn left onto the *tree-lined street*.	When they turned left onto the *tree-lined street*, his dog had the same idea, stopping at every single tree to mark her territory.
6.	Turn right at the *pink houses*.	When they reached the *pink houses*, they turned right. Famously in 1855, a resident threw dozens of pink roses from the balcony in protest of the construction of the first public toilet. Oh, how Strauss missed politics.
7.	Enter the *park* and turn left at the *table tennis table*.	When Strauss entered the *park*, there were two table tennis players fighting in the dust. Some people hate to lose, Strauss thought. He turned left at the *table tennis table*.
8.	Exit the *park* left.	"Wait!" One of the players ran up to Strauss, panting. "They are voting to separate our district into two! Exit the *park* left and go see for yourself!"
9.	Turn right at the veterinarian towards the *orange building*.	Strauss hurried straight ahead, turning right at the veterinarian towards the *orange city council building*. The veterinarian could wait, this was important.
10.	Walk past the *orange building*.	Passing the *orange city council building*, he could see lines of people voting. He grew outraged. "Separating our districts! And I didn't even know! It cannot be."

11. Take the *first right*.	He took the *first right*. (Pause) This was the proposed border between the two new districts. The street was filled with people, on one side shouting "5th! 5th! 5th!" and on the other side shouting "4th district! 4th! 4th!" But where could Strauss make a stand?
12. —	Feeling young again, he climbed the *tall skinny tree* on the corner, and joined in the shouting, excited to be involved once more.
13. Turn left at the *tall skinny tree*.	Turn left at the *tall skinny tree*, which stands in the same spot as the tree Strauss climbed, marking the controversial division of the 4th and 5th districts of Vienna in the 19th century.
14. Your destination is the *brown door* on the left.	Your destination is the *brown door* on the left, where Strauss's dog sat comfortably waiting for her friend.

Table 3.1: Shows both the landmark and narrative route instructions designed for the study. Landmarks are highlighted in italics. The corresponding photo of each landmark can be seen in Appendix B, and their locatitons can be seen in Figure 3.1.

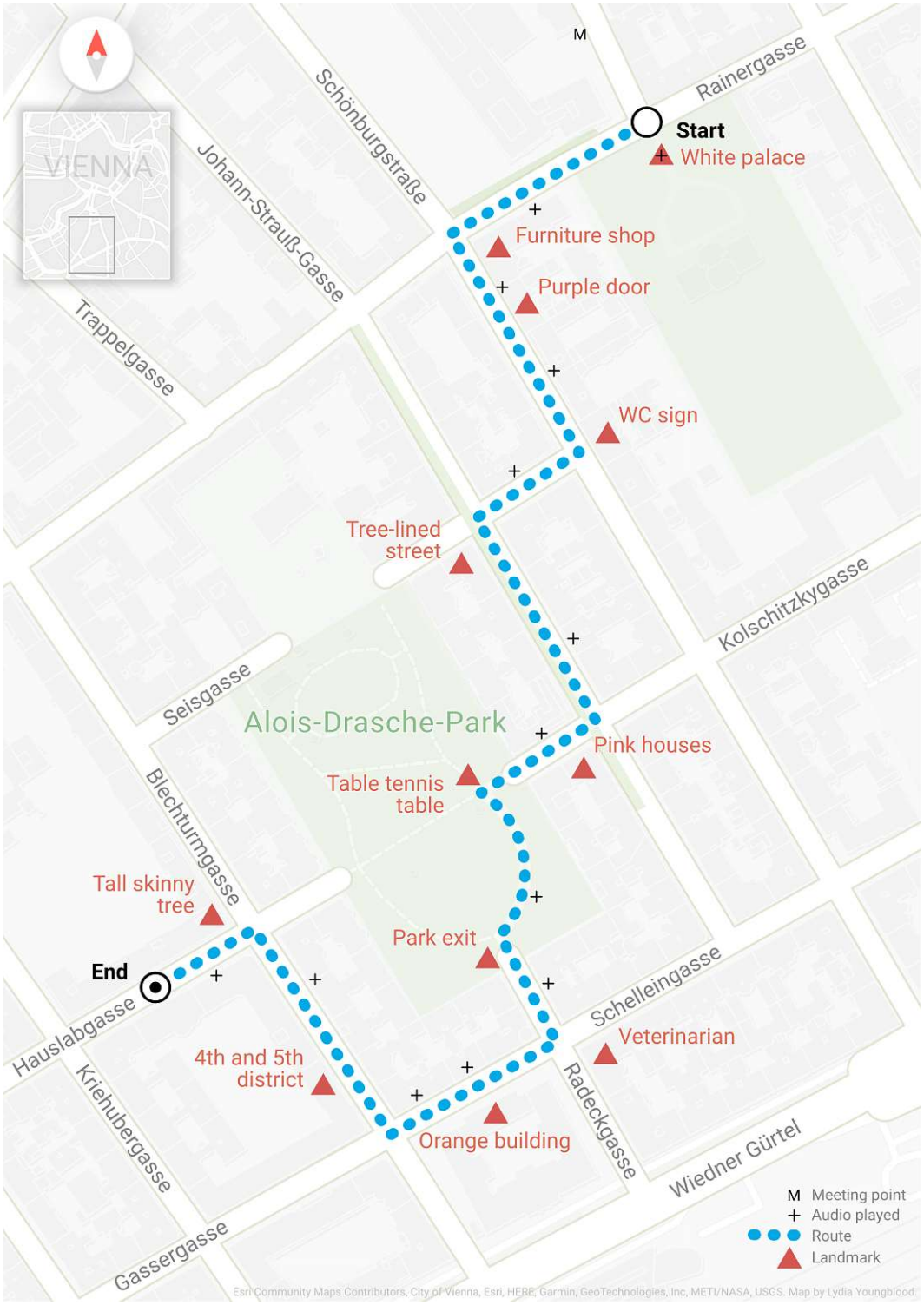


Figure 3.1: Overview map of the route and surrounding area. Participants met the researcher at the "M" in the far north of the map. The + symbol denotes at approximately what points the audio was played. The names of the landmarks are used consistently throughout this thesis. Photos can be seen in Appendix B. Map by the author.

Best design practices

To fulfill the second main requirement, best practices of designing navigation instructions were followed as closely as possible. These included using landmarks on the same side of the way as the turning direction (e.g. "Turn left at the furniture restoration shop;" where the furniture shop is located on the user's immediate left) (Klippel & Winter, 2005; Röser, Hamburger, Krumnack & Knauff, 2012), providing explicit actions at relevant landmarks (Denis et al., 2007; Klippel et al., 2002), and using landmarks that had good visibility as they were approached (Yesiltepe et al., 2021).

In a few cases, however, these best practices were flouted in order to better knit together the story. Instruction nine was one such case (see Table 3.1). The veterinarian where the user needed to turn right was located on the left side of the street, instead of on the same side as the turning direction. This caused some users to unnecessarily cross the street before turning right, however the orange building was included as an additional guide, as suggested by Denis et al. (2007) for difficult route segments.

Feedback about the directions was solicited from two colleagues and two friends, three of which were non-native speakers of English, mainly relating to the questions "Can you follow along with the turns in your mind? Can you imagine the story in space? Is it clear what I am saying? Are there any words that you do not know or that do not make sense, either from the recording or from the meaning?" It was important that non-native speakers review the directions, as the participant group was expected to be international.

Introducing landmarks into navigation instructions increases the memorability of the route (see Section 2.4.3). Therefore, landmark-based instructions were used as a control in this study. The landmark control instructions were designed using the same landmarks and turns mentioned in the narrative instructions, without any supplementary information. Thus, they were much shorter. There was, however, one error in creating the directions: the starting direction did not include the adjective white to describe the palace, though the narrative instructions did. The designed instructions were tested in a user study, and the following sections outline the approach used in designing the user study tests.

3.1.2 Assisted wayfinding

To test the narrative instructions, participants completed an assisted wayfinding task. This learning phase followed Wunderlich and Gramann (2021), using audio navigation instructions controlled remotely by the researcher. Audio-based navigation instructions have the advantage that they do not interfere with visual attention, and have been found successful in Rehrl et al. (2010); Wunderlich and Gramann (2021); Wunderlich et al. (2022).

3.1.3 Santa Barbara Sense of Direction Scale

Devolped by Hegarty, Richardson, Montello, Lovelace and Subbiah (2002), the Santa Barbara Sense of Direction Scale (SBSOD) was included in this study to give an idea

about the general spatial knowledge skills the group possessed, and to ensure that any potential differences between groups was not because some participants had superior spatial skills. The test is a self-reported measure; people "scoring higher on this scale do better on the tasks of wayfinding and spatial orientation that require an accurate configurational understanding of the environment" (Ishikawa, 2019, p. 200), and is a standard in the field, with high internal reliability (0.88) (Hegarty, Montello, Richardson, Ishikawa & Lovelace, 2006; Hegarty et al., 2002). It is important to note that the SBSOD is usually given in paper format, with all 15 questions on one page. For this research, the survey was adapted into a five-page online survey with three questions per page. Format and layout was maintained as closely as possible, but it is possible that adapting the survey to the online format changes the results.

3.1.4 Verbal generation of route directions

This method is used in the literature to assess users' internal representation of a route (Daniel et al., 2007). Participants are asked to verbally explain the route to the researcher as they remember it. Another popular method in the field for assessing users' acquisition of spatial knowledge is sketch maps. Verbal generation was chosen here instead of sketch maps, as it was hypothesized that more information about *why* a user remembered the route would emerge in verbal form. In addition, as Denis et al. (2014) note, verbal spatial information is particularly sensitive in capturing and conveying landmark-related information, which is important because landmarks play a central role in conveying route information (Daniel et al., 2007; Denis et al., 2007, 2014; Tom & Denis, 2004). Denis et al. (2007) note, however, that "while verbal recall provides a clear answer to the question of the memorability of instructions, it does not give any real indication of the participants' understanding of the overall spatial structure of the route" (Denis et al., 2007). As route memorability is the main focus of this study, this was not considered an issue. However, the task was combined with two other assessments to offer more comprehensive results.

3.1.5 Photo sequencing tasks

Photo sequencing is a method recognized as a measure of route knowledge (Denis et al., 2014; Kim & Bock, 2021). As Denis et al. (2014) put it, "remembering the relative position of landmarks along a route is a critical component of navigational memory." Similarly, this research used the method to assess the users' understanding of the sequence of scenes along the route. In Kim and Bock (2021), users had to select the three intersections in order that they had seen on a route, repeated for each of the three routes they had walked for a total of nine potential points, which were then used in a variance analysis with sketch maps. In Denis et al. (2014) and Daniel et al. (2007), 28 photo pairs were presented to the user and the total number of correct answers were averaged within each group. Analysis for the two photo sequencing tests in this research followed the method of Denis et al. (2014) and Daniel et al. (2007), but the overall number of photo pairs was reduced.

Where Denis et al. (2014) used all possible pair combinations, the photo pairs used in this study were carefully chosen based on two criteria: relatedness in either the physical world or in the narrative, and physical distance to each other. Photos of all landmarks except the starting and ending points (white palace and brown door) were considered as candidates for the photo task. Two photos were paired if they possessed either a strong causal relationship in the narrative[2] or were closely related in physical appearance[3]. Three pairs which were considered to have strong causal links in the narrative were used in the first photo sequencing task (Phase 2b) and three pairs were used in the second photo sequencing task (Phase 3b). Likewise, three pairs considered related in physical appearance were used in Phase 2b and three in Phase 3b. Which pairs each group received was decided via the second criteria, physical distance of the landmarks to each other in the real environment.

Selection of photo pairs for sequencing tasks

Related by...	Phase 2b	Phase 3b
Narrative causality	WC and furniture shop	Park exit and 4th & 5th
	Table tennis table and veterinarian	Tall skinny tree and pink houses *(f)*
	WC and pink houses	Tree-lined street and WC
Physical appearance	Purple door and 4th & 5th *(f)*	Furniture shop and orange build. *(f)*
	Pink houses and tree-lined street	Table tennis table and WC
	Park exit and tall skinny tree *(f)*	Veterinarian and tree-lined street

Table 3.2: Distribution of the photo pairs into groups for the photo sequencing tasks. Selection was based on narrative causality or physical appearance, along with physical distance between two landmarks, with further landmarks marked with *(f)*. To see images, see Appendix C, Figures C.5 and C.6.

The second criteria was based off of literature on the symbolic distance effect. Originally studied on symbols, the symbolic distance effect is "the fact that making judgments about two items is easier when these items are more distant from each other in a given dimension," (Denis et al., 2014; Moyer & Bayer, 1976, as cited in Denis et al., 2014). The effect has also been seen in photo sequencing tasks: Denis et al. (2014) found that response times for photo sequencing greatly decreased as the distance between a pair of given landmarks increased. For this reason, each potential photo pair was given a code of far (f) if one photo was five or more landmarks away from the other. Using this rating, the pairs were distributed into the two phases as evenly as possible. Because the route was short and the start and end points were excluded, each phase received only two far landmarks.

[2] e.g. Phase 3b, photo pair 3, seen in Appendix C, Figure C.6
[3] e.g. Phase 3b, photo pair 6, seen in Appendix C, Figure C.6

3.1.6 Route recognition task

Route recognition tasks (sometimes referred to as "cued-recall tasks" or "route direction tasks") have been used as a measure of how well the user remembers which action takes place at a particular point along the route. Routes can be thought of as a linked sequence of turns, which depend heavily on the landmarks cuing the turns (Huang et al., 2012; Münzer et al., 2006; Tom & Tversky, 2012; Tversky & Lee, 1999). The user's ability to recall what action to take at a certain point is regarded as a measure of the user's understanding of the route. In the literature, the method has been applied mostly as a photo task (Huang et al., 2012; Münzer et al., 2006; Wunderlich & Gramann, 2021). In this research, the method was adapted into an online text task and combined with a landmark sequencing task. Users needed to select the correct direction, which had been removed from the text (route recognition), as well as select which landmark came next (sequence of landmarks).

3.2 User study

3.2.1 Route selection

Vienna was selected as the location of the study in order to ease the burden of recruitment, as 21 students in the 11th intake of the Cartography M.Sc. program were finishing their second semester. The specific route was selected to be close enough to the university that students would reach the starting point easily, but in a neighborhood that was not too close to be well-known to participants. It was also desirable to have short city blocks that allowed for more turns in the short distance of 800m. Additionally, the location should not be overly 'rich,' as rich environments have been found to increase memorability for landmarks (Denis et al., 2014).

On a scouting mission, 26 points and three polygons were identified as potential landmarks and marked using Google Maps. 60 photos of the points were taken. These landmarks were then narrowed down to 13 based on usefulness for navigation of the particular route, visual or semantic salience, and potential to be incorporated into a narrative. Street network data from Open Data Österreich was used to map the landmarks and the route (StadtWien, 2021). Appendix B, Figure B.1 contains images of each landmark chosen for the wayfinding directions.

3.2.2 Participants and recruitment

20 participants (10 female, ages 18-44) were recruited via flyers posted around the university, word of mouth, and via an email distributed to the 11th intake of the Cartography M.Sc..

The paper flyer featured information and a QR code and link to a recruitment form created using Survey123 from Esri (https://survey123.arcgis.com) (see Appendix A, Figures A.1 and A.2). The email also included information about the study as well as a

link to the recruitment form. The recruitment form provided more detailed information about the study, confirmed that the participant could hear and see, possessed at least a B1 English level, asked what they would like to be called and asked in which district the participant lived. If they wanted to participate, they provided their email. The final question was ultimately unimportant in the study, as it was more important whether the participant was familiar with the research area than whether they lived in a nearby district.

Participants were then contacted via email to schedule a time to complete the study (all email correspondence for the entire study can be seen in Appendix A). Scheduling was done using Xoyondo.com (https://xoyondo.com/), which allowed for anonymous (except to the researcher) selection of the participant's preferred time. Registration was then confirmed via email and the starting location was shared. The participants were also given the opportunity to fill out an informed consent form and to send it back as an email attachment to the researcher (see Appendix C, Figure C.1). Those who did not send the form were asked to read and fill out a hard copy at the very beginning of the study appointment.

3.2.3 Procedure

After recruiting participants, each participant was assigned a random number between 11 and 120, which was then used as their identifier on all subsequent tasks. The entire procedure is broken into three phases: Phase 1: Learning, Phase 2: Verbal generation of route directions and first photo task and Phase 3: Route recognition and second photo task. Figure 3.2 shows an overview of the phases.

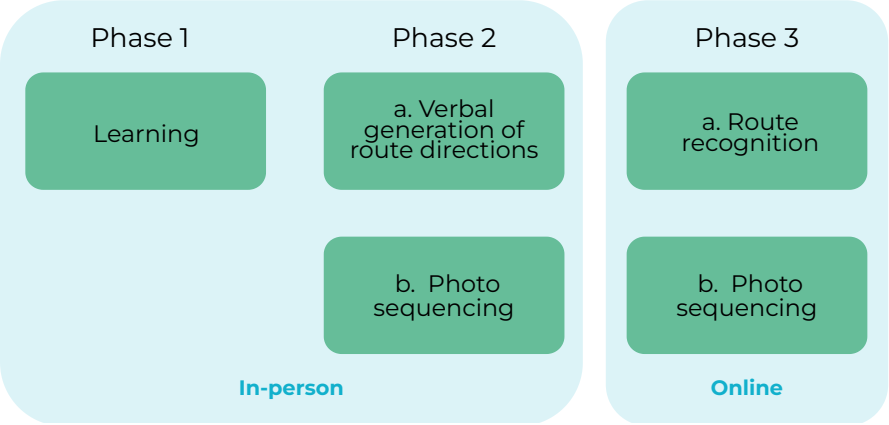


Figure 3.2: Overview of the three phases of the user study. Phases 1 and 2 were completed in-person, while Phase 3 was completed one week later online.

Phase 1: Learning

The first task was an assisted wayfinding task. Each participant was met for their individual time-slot at the starting point (see Figure 3.1). Research began following a

written research protocol (see Appendix C, Figure C.2).

The participant was introduced to the experiment and the researcher and was informed that the research was beginning. They were then provided with a pair of over-ear headphones (Flagship ANC, Status) and a size A5 laminated paper map of the route inside of a small bag (Figure 3.3). Participants were instructed that they would receive audio navigation instructions through the headphones, but that they could use the paper map if they needed to. If further clarifying questions were asked, they were told to imagine their phone with a map was in their pocket that they could look at if something was unclear. These instructions were purposefully slightly ambiguous so as not to sway the user towards or away from using the map. A brief audio test was completed, which allowed the participant to adjust the volume on the headphones.

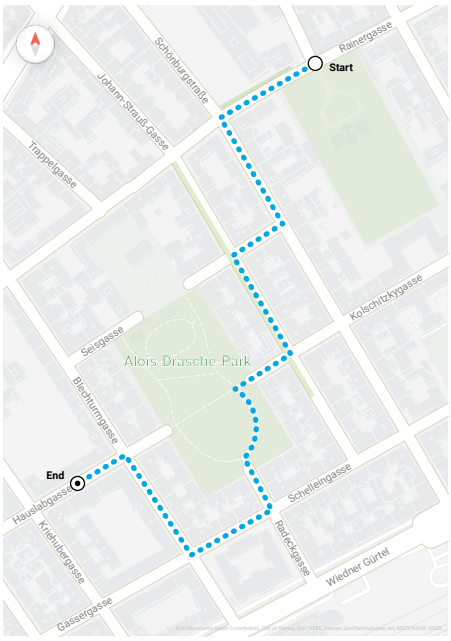


Figure 3.3: Simplified route map participants received. Design based on Google Maps, map by the author.

Figure 3.4: Demonstration of the learning phase.

Figure 3.5: Researcher view to control directions.

After answering any questions, the participant was led to the starting point. They were reminded to watch out for traffic and stay safe while navigating. The option was given to reduce the noise-cancelling function of the headphones. Then the navigation portion began.

The audio directions were previously recorded by the researcher and were played via video through a Bluetooth connection from the researcher's iPhone SE (3rd generation, Apple). This allowed for free movement of the participant. Video was used so that the screen showed the text that the participant was hearing, with a three second pause between

each instruction so the video could be smoothly paused by the researcher. Figure 3.5 shows the view of the phone screen.

Upon hearing the first direction, the participant began the route. Figure 3.1 shows the points where each navigation instruction was played. A + sign before a landmark indicates approximately where the user heard the instruction. The researcher followed approximately 1.5 meters behind, playing and pausing the instructions (Figure 3.4). Upon reaching the end of the route, the participant was congratulated, and the headphones were cleaned while walking to a nearby table to complete the next phase. This location varied slightly due to availability of tables or benches, but was always located on the west side of Alois-Drasche park, out of view of any landmarks when possible.

After reaching the interview location, the researcher set up a laptop (2015 MacBook, Apple) for the participant to fill out a brief demographic survey (Appendix C, Figure C.3) and to complete a computerized version of the SBSOD (Appendix C, Figure C.4). While the participant completed the surveys, the researcher's iPhone was set up to record with the built in microphone of Apple EarPods. A backup recorder was also set up. Upon completion of the survey, the microphone was clipped to the participant's shirt and the participant was told that audio recording would begin. The survey took about five minutes to complete, and was completed between the learning phase and Phase 2a to introduce a slight delay in recall.[4] The set-up is shown in Figure 3.6.

Figure 3.6: Set-up of the interview and photo sequencing task. Image by the author.

[4]Remembering routes is affected by primacy and recency effects, two phenomena found in the recall sequential lists. Items at the beginning and end of the list are more likely to be remembered than items in the middle (Baddeley, 1999; Reisberg, 2010). Introducing an active delay, where the user is occupied with some other task, can reduce this effect (Reisberg, 2010).

Phase 2a: Verbal generation of route directions and interview

Audio recording began with a semi-structured interview, with questions asked based on the participants' answers to preceding questions, except for the first question, which was:

> I want you to imagine that as we were walking just now, you dropped your keys. Luckily, your friend is at the white palace where you started and is coming to meet you. They don't know how to read maps, but you are on the phone with them now. Can you describe to them exactly how to go from the white palace to the brown door so that they retrace your steps?

This question was designed so that the user could generate a set of verbal instructions based on their memory of the route. Based on their answer to the question, the following follow-up questions might be asked:

- What helped you remember all those details?
- I see that *(X)* seemed to stick well in your memory, why do you think that is?
- *(If they suddenly remembered a landmark)*: Good, and do you remember what you needed to do there?
- One section you forgot seemed to be *(X)*. Do you remember what you needed to do there?
- You forgot a few points in the route, why do you think that is?

The tone of the interview was casual and conversational. The researcher attempted to guide the participant back to the topic if there was a major divergence. The questions were designed to better understand how they remembered some elements of the route better than others, and also to give them the opportunity to fill in any missing elements as they arose. If the participant omitted part of the route, they were prompted with a turn or landmark that they had mentioned, and asked if they remembered what came after that. If they were unable to remember, the next landmark was told to them and they were again asked if they remembered what followed. During the course of the interview, major mistakes were corrected by the researcher. As a final question, each participant was asked "Was there any other part of the route or directions that you remember or any other comments that you would like to add?" This concluded the interview section and recording continued for Phase 2b.

Phase 2b: First photo sequencing task

Participants were presented with 10 x 15cm printed photos of scenes seen during the walk. The photos were presented in pairs, with six total pairs, for a total of 12 photos. The order that the two photos were shown to the participant was random, but the first

10 participants received pair one, then pair two, and so on until pair six, while the last nine participants received pair six first, then pair five, and so on until pair one. This was to ensure that any patterns were not due to the ordering of the pairs.

Participants were asked to order the photos from left to right, placing the scene that they remembered seeing first on the left, and the one that came afterwards on the right. A brief training phase with two dummy objects and two dummy photos ensured that they understood the task. After ordering a pair, the participant was asked why they were able to remember the order. Errors in the photo pairs were recorded.

This concluded the in-person phases of the research. The participant was thanked and was reminded that a survey would be sent via email after one week and encouraged to complete it. They were informed that compensation (if selected) would arrive one to two days after submitting the one-week survey.

Phase 3a: Route recognition

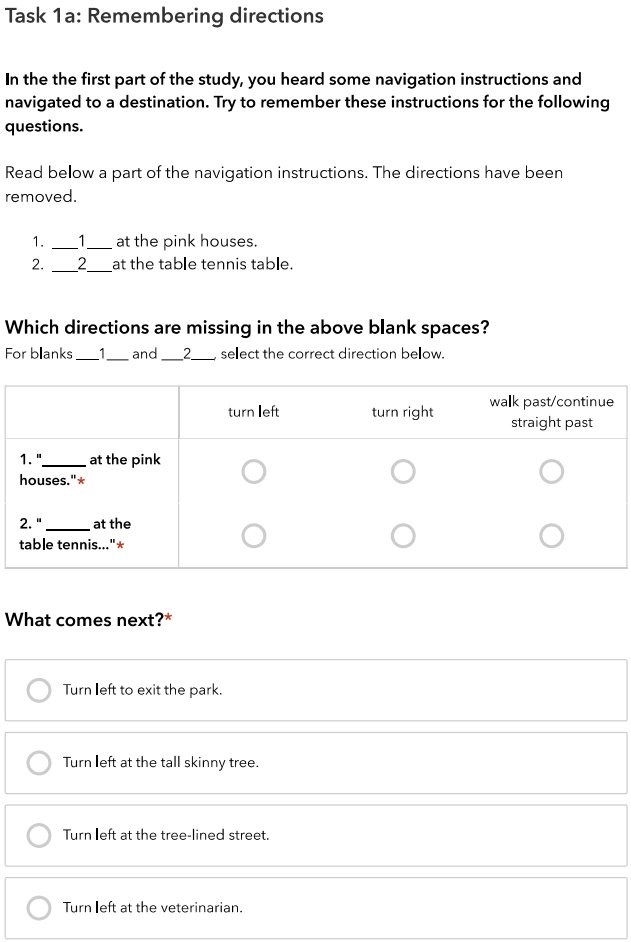
One week after completing the first phase, participants received an email with a link to complete an online survey (see survey example in Appendix C, Figure C.7). In order to keep the amount of data processing manageable for this research, the user was not asked to repeat the route in text form one week later. Instead, a second task was designed to assess participant's route recall. The task was a combination of two methods in the literature: sequencing of landmarks and route recognition. The theoretical importance of landmark sequencing and route recognition tasks have already been explained in Sections 3.1.5 and 3.1.6. A period of one week was chosen based on research indicating that information remembered after one week is similar to that remembered after one month (Baddeley et al., 2015).

This phase of the survey was designed to test participants' memory of each action presented at a landmark and the sequence of landmarks. The route directions were divided into three sections, and then presented out of order. The first question set was about the middle of the route, the second question question about the end of the route, and the third question set was about the beginning of the route. The participant was prompted with the route directions they had received, but with the actions (turns or other) blanked out. First, they needed to select the correct action for each blank in the provided instructions. Then they needed to select which action and landmark came next from a list of four options. Figure 3.7 is shown as an example of one set.

The participants who were originally in the landmark condition received landmark instructions and the participants originally in the narrative condition received narrative instructions. The instructions were the same as the original, edited slightly to remove any obviously revealing information that would make the task too easy. For example, the seventh instruction in the narrative condition (see Table 3.1, direction 7) became:

> There were two table tennis players fighting in the dust. Some people hate to lose, Strauss thought. He _____ at the table tennis table.

After completing the first section of the online survey, Phase 3b, another photo sequencing task, was presented.


Task 1a: Remembering directions

In the the first part of the study, you heard some navigation instructions and navigated to a destination. Try to remember these instructions for the following questions.

Read below a part of the navigation instructions. The directions have been removed.

1. ___1___ at the pink houses.
2. ___2___at the table tennis table.

Which directions are missing in the above blank spaces?

For blanks ___1___ and ___2___, select the correct direction below.

	turn left	turn right	walk past/continue straight past
1. "_____ at the pink houses."*	○	○	○
2. " _____ at the table tennis..."*	○	○	○

What comes next?*

- ○ Turn left to exit the park.
- ○ Turn left at the tall skinny tree.
- ○ Turn left at the tree-lined street.
- ○ Turn left at the veterinarian.

Figure 3.7: The first page of the route recognition task for the landmark group. Participants first selected the missing action and then which landmark and action followed.

Phase 3b: Second photo sequencing test

The second task in the online survey phase was identical to the in-person photo pairs test, but adapted to the online survey. Each photo was labeled “A” or “B.” Here, participants needed to select photo “A” if they saw that scene first, or photo “B” if they saw the scene in “B” first. Participants confirmed that they understood the task via a training pair.

Six photo pairs were presented, different pairs from Phase 2b. 10 of the 12 photos had been seen in the first photo task, and two were new. As in the first task, the first 10 participants received pair one, then pair two, then pair three, and so on, while the rest of the participants received pair six, then pair five, and so on. Additionally, for the last

nine participants, the labeling of the photos was reversed, so that photo "A" in pair one became photo "B" and vice-versa. Again, this was to limit any bias in the presentation order of the photos within the group. At the end of the photo pairs test, the participant was thanked and the research was completed. Upon receiving the survey, the researcher transferred 7€ via IBAN if applicable.

3.3 Data analysis

A diverse data set was generated by the aforementioned methods. Data was analyzed both qualitatively (verbal generation of route directions, interviews, reason for selecting photo pair order) and quantitatively (demographic and SBSOD questionnaire, route recognition task, and photo sequencing tasks).

3.3.1 Learning (Phase 1)

Demographic information was visualized. SBSOD scores were analyzed following recommendations by Hegarty et al. (2002): scores for all positively-worded questions (questions 1, 3, 4, 5, 7, 9, 14) were reverse-coded so that all scores for the 15 questions could be averaged for each participant. Therefore, a score of one would correspond to a poor SOD, and seven to a good SOD (Hegarty et al., 2002).

3.3.2 Verbal generation of route directions (Phase 2a)

Interview audio was transcribed using Otter (Otter.ai). Transcripts were then edited for clarity. The participants' descriptions of the routes were rated by the researcher into one of three categories: "good," "fair," and "poor." The rating method is based on a similar method used in Denis et al. (2014) and Daniel et al. (2007). Both of these studies, however, only present the percentage of routes ranked as "good." Here, three categories were created. Table 3.3 shows the criteria for the categories.

In cases of ambiguity, the researcher looked further into the interview to understand whether the participant clarified or further developed their expression of the route. Some participants gave a route description that was missing a segment, but immediately after completing the description filled in the hole on their own initiative as more memories came back. The researcher included these in the assessment of the route quality if the user brought up the missing segments themselves. Transcript 70 provides a good example of this. All transcripts can be seen in Appendix D.

3.3.3 Photo sequencing tests (Phases 2b & 3b)

The two photo sequencing tests each produced four different groups for data analysis: one narrative group that had received image pairs one through six (NAR16), one narrative group that had received image pairs six through one (NAR61), one landmark group that had received image pairs one through six (LM16), and one landmark group that had received image pairs six through one (LM61).

Ratings for route descriptions

Rating	Description
Good	• Route is near perfect; if followed, directions will easily bring listener to their goal. • Very few mistakes in either indication of direction or description of landmarks. • All or almost all parts of the route are discussed.
Fair	• Route is ok; if followed, directions will lead user generally in right direction but may have to stop and ask for additional help. • Some mistakes in either indication of direction or description of landmarks. • Most parts of the route discussed, although some short segments may be missing.
Poor	• Route is poor; unable to be followed in some or all places, listener very unlikely to reach goal. • Many mistakes in either indication of direction or description of landmarks. • Large segments (> 3 or more turns) may be missing.

Table 3.3: Shows the criteria for rating the user-generated route descriptions.

The number of correct photo pairs was added up for each participant. For example, if a participant had gotten five pairs correct, they received a score of five. There were six total pairs; therefore, the highest possible score was six. The scores from the two landmark groups were tested for significant difference between groups using the Kruskal-Wallis test (KWt), a one-way Analysis of Variance (ANOVA) on ranks for non-parametric data sets. If the differences were not significant, the two landmark groups could be combined and analyzed together. The same was done with the two narrative groups. This was done for both the first and second photo sequencing test.

In the first photo task (Phase 2b), each participant was asked "*Why do you remember*

it that way?" after sequencing each photo pair (six answers per participant). This qualitative data was analyzed based on themes emerging from the answers. In the second photo task (Phase 3b), each participant was asked just once after sequencing all photos *"In general, how did you remember all of your photo answers? Did any information in the instructions help you remember your answers?"* Similarly, emergent themes are analyzed.

3.3.4 Route recognition (Phase 3a)

The number of correct answers was added up for each participant. Averages were then calculated within each group. There were 12 total questions; therefore, the highest possible score was 12. Averages for each group were computed.

The mixed-method design of this study and the subsequent analysis addressed the research questions outlined in Section 1.2. The following chapter presents and discusses these results.

CHAPTER 4

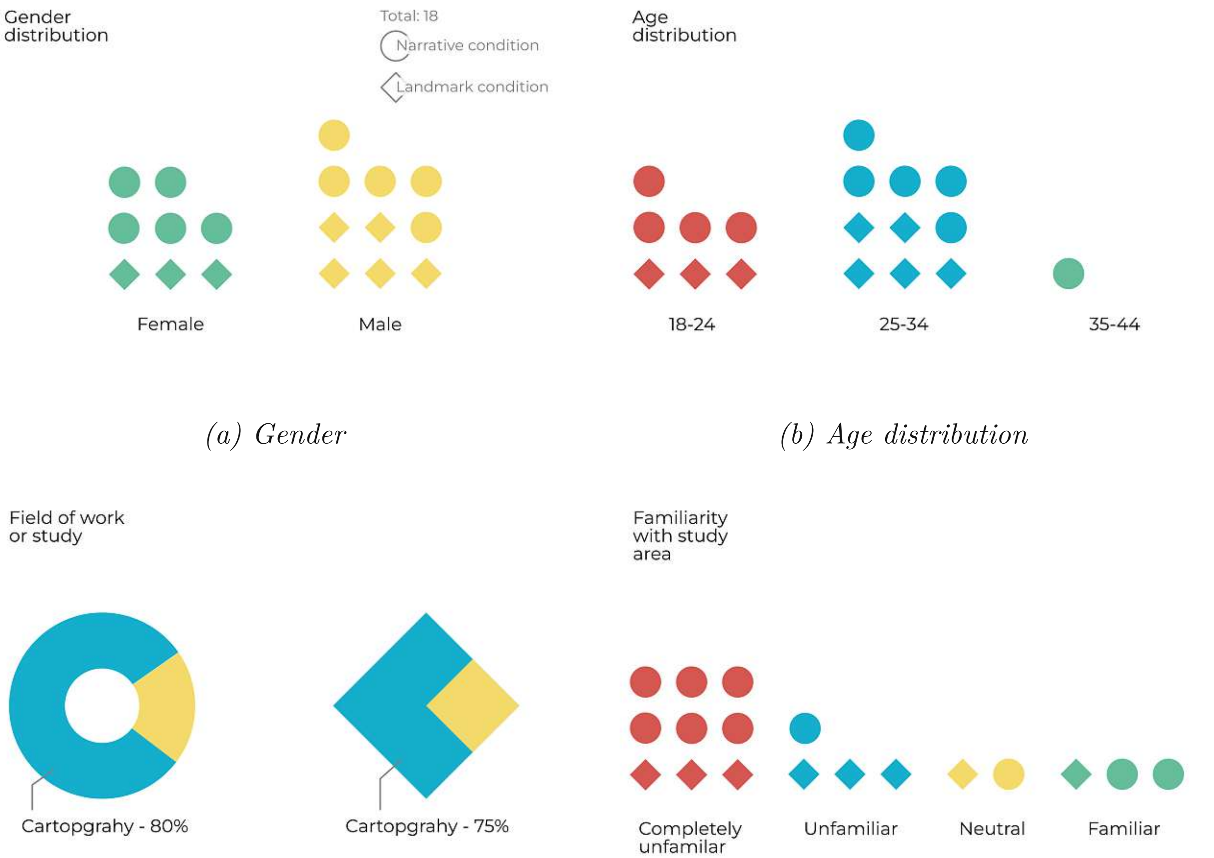
Results and discussion

This chapter presents the results that arose from each of the three phases of the wayfinding study. Each phase is presented separately, with a brief discussion of results. Then, a general discussion is presented.

4.1 Phase 1: Learning

The learning phase was completed successfully over five sunny and hot days in Vienna. Two participants fell ill last minute with COVID-19 and only one was replaced. One participant was eliminated from the study because they did not complete the third phase, reducing the total final number of eligible participants to 18. Figure 4.1 shows demographic information for the participants.

Eight female and ten male users participated, with three females in the landmark condition and five in the narrative condition (Figure 4.1a). Ages (Figure 4.1b) were well distributed between the landscape and narrative groups, with all participants falling between the ages of 18 and 44. Likewise, both groups had a similar number of people with a background in cartography; 80% of the narrative group were cartographers, 75% for the landmark group (Figure 4.1c). As a group, the landmark condition was slightly more familiar with the study area than the narrative group, but still most participants fell into the categories of "completely unfamiliar" and "unfamiliar" (Figure 4.1d). It is important to note that two participants in the landmark group, both of whom had near perfect recall on every task in the study, mentioned independently that they train their memory frequently and like memory games. This may have slightly imbalanced the results.

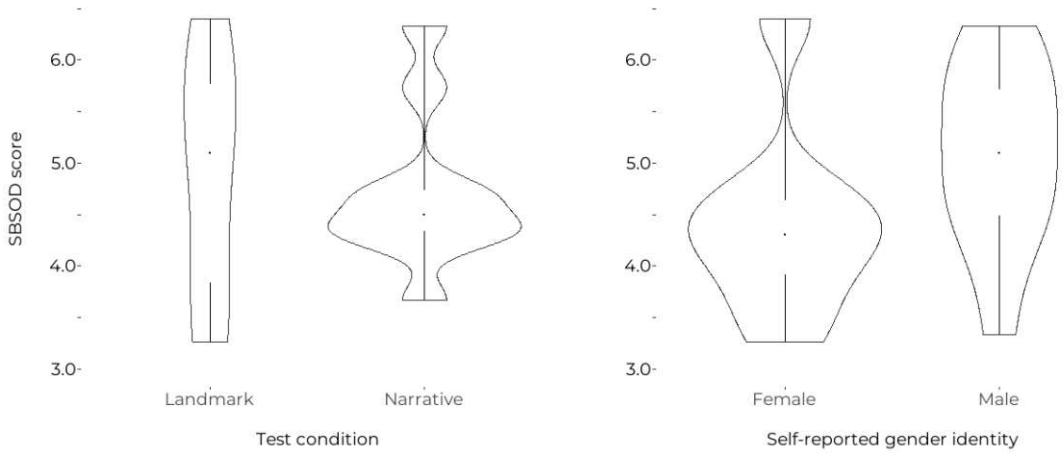


(a) Gender *(b) Age distribution*

(c) Field of work or study *(d) Familiarity with study area*

Figure 4.1: Demographic information for the 18 participants of the user study.

The overall SBSOD score for all participants was 4.78 (SD = 0.962). The SBSOD scores were similar in the two groups: the landmark group had an average score of 4.87 (SD = 1.21) and the narrative group an average score of 4.71 (SD = 0.772) (Figure 4.2a). The SBSOD scores were additionally grouped by gender and analyzed: females had a lower average score of 4.41 (SD = 0.938) compared to males with an average of 5.08 (SD = 0.917) (Figure 4.2b. Overall average scores and the difference between male and female participants are consistent with the literature Huang et al. (2021); Montello and Xiao (2011), so SBSOD scores are considered balanced in this study.



(a) Average SBSOD score by study condition *(b) ...and by gender identity*

Figure 4.2: Average Santa Barbara Sense of Direction Scale (SBSOD) score grouped by study condition and gender identity. These violin plots show the distribution of the group (curves) in addition to the median (dot), IQ range (blank space) and whiskers (lines).

4.2 Phase 2: Verbal generation of route directions and first photo sequencing test

After the learning phase of the study (Phase 1), users completed Phase 2, which consisted of two tasks. The first was to explain the route in detail to the researcher, generating a set of route directions, and the second was a photo sequencing task. One researcher error arose during Phase 2 (see Section 4.2.2).

4.2.1 Phase 2a: Verbal generation of route directions

Overall, participants were able to remember and describe the route quite well. In total, 11 routes were rated as “good,” four as “fair,” and three as “poor.”

Table 4.1 shows the resulting ratings of the route directions. The two groups had similar performance: in the landmark group, five of eight (62.5%) of routes were categorized as good, compared to six of ten (60%) in the narrative group. While at first glance this

Results of rating route descriptions

Condition	Rating	Number of routes rated	Percentage of total (%)
Landmark (n = 8)	Good	5	62.5
	Fair	2	25
	Poor	1	12.5
Narrative (n = 10)	Good	6	60
	Fair	2	20
	Poor	2	20

Table 4.1: Shows results of rating the user-generated route descriptions.

seems relatively low, only two routes were rated as poor in the narrative group, and one in the landmark group. This means that in both groups, most users recalled a route that would allow the follower to head in the correct direction with little or no additional help, and that all or most of the route was discussed. In addition, the task was relatively difficult; the route had nine reorientation points, and many participants expressed that this task was quite difficult for them. Some participants expressed that they would have no trouble at all re-walking the route, but that telling it to a friend was very difficult. As Participant 62 mentioned:

> **62** So I may not remember everything. So would maybe not be able to describe it verbally. But if I'm again at that place, I will be able to guide you because I remember very visually the place... but just describing it, like, over phone...It will be- it's harder.

It was also clear from some participants' behaviour that the task required serious cognitive effort. The time between the initial question and the answer on the transcripts is also a good indication of this (e.g. Participants 33 and 42). In addition, the results are similar to Denis et al. (2014), who found 50% and 66% of routes rated as 'good' in a visually dull environment and visually rich environment, respectively.

Asking participants to describe the route verbally was chosen because it was hypothesized that users would be able to provide more information about why they remembered the route in their answers than with sketch maps. However, this was not the case. For the most part, participants in both groups answered similarly: they gave concise, landmark-based turn-by-turn directions, mentioning only a landmark and an action. Compare Participant 39 from the landmark group with Participant 98 from the narrative group:

> **39** ...exit the palace and turn left and then turn left at the furniture store. Then walk past the purple door. Turn right at the sign for the toilets. Enter

the park and turn left at the table tennis table. Exit the park and walk straight ahead...

98 Then there was a toilet sign and there you turn right and then the next one left...it was a street with lots of trees. Then I think the next one was right. And then straight and then...there were some pink houses and just before you are at the pink house you turn right again. And then there's a park and you turn left in the park and then you go... like a quarter circle and then you exit and on the left again.

The general absence of mentions of the narrative could have been due to the way the prompt was formulated. Participants were asked to describe the route to their friend so that the friend may follow and look for the keys. Additional information, such as where Johann Strauss met his wife, may have been seen as irrelevant to the friend's task. In fact, Participant 50 brought this up in the interview, "I need to give a generalized view of the path to follow because I guess he's [friend on phone] not interested in...if that building, I don't know, has any value. Just like, go quickly? Probably I need him to go fast, I need my keys" (Transcript 50). An interesting alternative is to ask the participant to describe the route so that their friend can memorize it and to see which information the participant chooses to include.

Mentions of narrative in the semi-structured interviews

While the narrative was barely mentioned in the users' route descriptions, it was brought up by all ten participants in the narrative condition in the interview that followed. Sometimes participants just mentioned characteristics or events described in the narrative:

Lydia Youngblood There were two places that you didn't mention. You mentioned the turns, but you didn't mention the place. One was the-

104 The veterinarian.

Lydia Youngblood Yeah. Do you remember where that is?

104 I think it was on the corner from the mayor building. And we didn't care for it because we had to go for the district problem.

Lydia Youngblood So you said we didn't care for it, you mean, like in the story?

104 Yeah, in the story, but like I see it, I saw there was a sign with a cat and a dog.

Lydia Youngblood And you really remembered the toilets...what what made it stick in your mind?

33 I think it's because it's the oldest one in Vienna. Yeah. I think that that was what made it stick in my mind.

Other times participants mentioned that it helped them remember a landmark or a part of the route:

> **Lydia Youngblood** Were there any points...that really stuck with you?
>
> **70** I don't know, maybe the furniture shop? I don't know why. And the purple door, probably from the backstory, I would say...those really like struck in my memory, specifically the furniture store. Because it was also saying like: oh, how I wish to be sat down right now. And I feel like, okay, that's kind of interesting.
>
> ...
>
> **Lydia Youngblood** You also remembered the orange building pretty well. And multiple times you've brought it up. Why do you think you remember that one?
>
> **70** Probably because I feel like it had a lot of essence to the story. It's like... the people, the line... I think it also connects with the fact that he also came to this tree to join the other people. So I guess that's probably why. And it was mentioned also a lot on the audio like, of how he... kind of like... it also affected like his emotions while walking. So I guess that's why I also remember it.

> **86** [Speaking about why the border between 4th and 5th district was interesting] And it was also nice, the way you narrated it, because, like... you mentioned that there are people on both sides. Fourth, fifth. And so this also, I think, helps the person as you're walking to also kind of animate it in your mind.

> **27** Yeah, I remember the oldest toilet of the city. And I really would like to see it. Of course it might be interesting. And that was also interesting that they were protesting against it with the roses.
>
> **Lydia Youngblood** Do you remember where that happened in the environment, that protest?
>
> **27** Yeah, the buildings were on a crossing. And they were also kind of purple colored? And it's... I think it was aft- no, before the park.

The quote above from Participant 27 is particularly interesting because the participant performed poorly on the route description task, giving a very brief overview of general directions. This segment described in the quotation was forgotten by the participant in the route description task, however, here they describe the segment perfectly. This is a case where the narrative came up in the interview, however the participant did not use that information in their route description.

That all ten participants in the narrative group later discussed the narrative in their interviews is intriguing. It suggests that at least some parts of the narrative remained in the memory after navigating. However, the ratings of the route recall task show no difference between the two groups.

General reception of the instructions across both groups

One important result that arose from the interviews, despite not being explicitly asked, was the general positive reviews about the type of directions across both groups. In the landmark group, comments were very positive:

> **39** I'm not that good at receiving directions. When I drive somewhere, I usually take the wrong turn at least once if it's a new area. So this worked kind of better. I don't know why. But it was very clear. I always knew where to go. Like as soon as I saw the point. I knew where to go immediately.
>
> ...
>
> It was pretty clear and easy and uncomplicated, so there's not much to think about.

> **42** I think yeah, the navigation itself helped me a lot. Like, I think with only the directions, like turn left, right... Like without those symbols, I wouldn't have remembered that much I think. Or it's easier to describe now.
>
> ...
>
> I think it was also very exciting. What's coming, because I didn't expect, like at the furniture shop. I was like, Okay, how should I find this? And then it was just on my left. And then was very exciting. And where's the sign? And then? Yeah, it was so specific. And I didn't expect it.

> **113** I think for me...the audio directions were actually pretty nice. Because it actually like, you know, highlighted sort of an important thing in that surroundings. So for me, that was very interesting. Because when I actually like... understood that audio directions, quite clearly, I didn't feel the need to see a map to visually orient myself anymore. So that was very, very helpful (Transcript 113).

Meanwhile, in the narrative group, users mentioned that they enjoyed the route directions, though some noted that they needed some time to get used to the style:

> **70** Yeah, it was pretty easy to follow the direction to be honest. So I did not feel the need to check [the map] out. I feel like it was totally clear.

> **30** And it was like the story was explaining about this line of people voting in the city hall. I think it's super nice, that. Perhaps in the beginning, it takes time to get used to it. Like that you have to follow the instructions, but it's a story at the same time, but once you are in, you kind of get it (Transcript 30).
>
> **98** But I really really like it. I think it's interesting. And I didn't think it would work this good.
>
> **Lydia Youngblood** So when you started out, you were like, hmm.
>
> **98** Yeah. But then going in... I felt confident (Transcript 98).

No user said that they did not like the directions, though it is important to remember that participants were not explicitly asked for their preference. Nevertheless, many participants gave positive and at times quite enthusiastic feedback about the instructions, independent of which group they were in. Results from the narrative group indicate that there is a learning period for some for this type of narrative directions. The learning period should be accounted for in future studies by the incorporation of a training phase. The results from Phase 2a further encourage the design of landmark-based route directions.

4.2.2 Phase 2b: First photo sequencing test

The task proceeded smoothly with one exception. Due to researcher error, six people in the narrative condition received the photo pairs ordered one through six ($n_{NAR16} = 6$), while four received pairs ordered six through one ($n_{NAR61} = 4$). There should have been five in each group. Due to the very small sample size, it is possible that the mistake had a slight impact on the average result of each group. However, as a KWt confirms, the differences between the four groups were not significant.

The KWt affirmed that the average number of correct photo pairs showed non-significant differences ($H = 3.073$, $p = 0.3806$, df $= 3$). This meant that the order in which the photo pairs were presented likely had little effect on correct answers. Therefore, the two landmark groups, LM16 and LM61, were combined and analyzed together, as were the two narrative groups, NAR16 and NAR61. Of the six photo pairs presented, the mean number of pairs eliciting correct responses was 5.5 (SD = 0.756) for the landmark condition and 4.8 (SD = 1.23) for the narrative condition. The difference is not significant ($H = 1.55$, $p = 0.2131$, df $= 1$).

Both groups showed high average confidence in their answers for the photo task. On a scale from one to five, with five being "extremely confident" and one being "not confident at all," the average answer was 4.25 (SD = 0.463) for the landmark group and 4.10 (SD = 0.738) for the narrative group.

For each photo pair, participants were asked why they remembered the pairs in the order they chose (*"Why do you remember it that way?"*). Answers were categorized into themes

and show similar results across both groups, with one exception: the narrative group additionally discussed the narrative, presented here first.

Narrative

Nine of ten participants in the narrative condition brought up a part of the narrative for at least one photo answer when responding to the question. This is an important finding, as despite the statistical similarities between the two groups, it suggests that the narrative still affected the route memory in some way. Sometimes a participant used the landmark's identity in the narrative simply as an identifier (instead of, for example, it's visual or semantic salience, or the name of the landmark used in the instructions, as was common in the landmark group). Participant 104 said about the second photo pair:

> **104** We're entering the park and then there is the table that they're like playing and fighting, and then we exit and...after we exit the park we reach the veterinarian and then we go to the right.

At times the narrative seemed to be used to distinguish two photos that looked similar, or to recognize the scenes, such as Participant 27 choosing the sequence of photo pair five:

> **27**...is it not the same? Ah! This is the street where the dog wants to pee and these are the houses with the flowers. I think this was... this was first [points to tree-lined street].

Sometimes participants seemed to use the narrative more as an anchor point related to the landmarks. Participant 70, speaking about their correct answer of the second photo pair is a good example:

> **70** ...And then he turned right, and he reached to the orange building. So that's... this is like after he left to join the people I think, after he left the park.
>
> **Lydia Youngblood** Because he had learned about the people in the park?
>
> **70** Yeah. So it was like he turned... I remember turning left. And then he meets another person and the person tells him like to go take a look. So he also turns left and goes to join them. Yeah, I think.

"Them" in this case is the group of protesters along the border of the 4th and 5th districts. This part of the narrative has very strong causality; Strauss proceeds to the protest because he hears about it from people in the park. Participant 86 felt similarly:

> **Lydia Youngblood** Why do you remember it that way?
>
> **86** The same. Because it's too powerful...this is the border at the end so much later in the story.
>
> **86** Yeah, this is... this is the very like strong part of the story, it helps you also. Because I think that like... like in Europe, I think every other street looks the same. I mean, you know, especially in the suburbs, I would say, because I think we are also a bit not in the center right now.

Participant 30 is another good example, relying on the narrative to identify the order of photo pair one, which included a photo of chairs in the window of the furniture store: "I remember [the narrator] said he was already tired after 50 meters I think. And then he had to sit" (Transcript 30).

Position of landmark relative to start or end

Most frequently mentioned for both groups for why a photo sequence is remembered is the relative position of one of the landmarks shown to the beginning or end of the route. Every single participant mentioned remembering a sequence because one landmark was close to the *beginning* of the route ("This was literally the first direction that I got, take the left at the furniture store" [Transcript 113]), and all participants except one mentioned remembering a sequence because one of the landmarks was clearly near the *end* of the route ("The tree was close to the destination. And the park was before, yeah" [Transcript 42]). This is unsurprising given that the first and last parts of routes are known to be better remembered than the middle (Cornell, Heth, Kneubuhler & Sehgal, 1996; Hilton, Wiener & Johnson, 2021; Meilinger et al., 2016).

Uncertainty and mistakes

Seven participants (three landmark, four narrative) explained that they remembered a landmark or sequence of two landmarks particularly well because they had either made a mistake and had to be called back (e.g. "this is where I made the mistake with the trees" [Transcript 104]), or because they were feeling uncertain when navigating.

The uncertainty can be broken into four categories. One was a language or hearing misunderstanding (e.g. Participant 15 upon seeing the third photo pair: "because this was the tree line that I was doubting" [Transcript 15][1]). The second category is when the next direction did not align with expectations (e.g. Participant 104: "Also yeah, the toilet was first because I was thinking that we were going to reach the toilet. That's why I was confused" [Transcript 104]) Third is searching for landmarks (e.g. "actually I couldn't find like the reference to the toilet in the street...yeah, I was like, what, where? So that's how I remember it again" [Transcript 86]). The fourth category is general

[1] In Phase 1, the participant did not understand the term "tree-lined" and wanted clarification, given verbally during the study as "line of trees." Three participants required this clarification.

confusion (e.g. “this one was before the park and then this one was right after, when I had to turn and I didn’t know where to go” [Transcript 30]).

Slope

When selecting a route, the slope of the terrain was only considered insofar as to avoid steep hills for the participants so as not to overburden them with physical difficulty. The gentle slope upwards from landmarks 3 to 6 and downwards from landmarks 11 to 12 was useful to some participants when recalling the directions.

> **33** Okay, this was actually very hard for me. But the only time that we went downwards was pretty much at the end because I think there was this big tree that he’s supposed to climb. Then he went left and then it ended. And this was the only time that we went downwards.

It is important to note that slope was frequently mentioned alongside other themes. In the quote above narrative action is also mentioned. Participant 60 mentions three themes in one answer:

> **60** Because I was thinking that this is probably near the main station where my car is at the moment. I was thinking huh, I could go look at it after if it’s still there and nobody stole it. And that must have been after the park because it’s higher up on the hill.

Here the participant mentions a variety of strategies: personal connection, a global landmark, and slope.

Miscellaneous

Reasons cited less frequently for memory included personal connection to either a landmark (“Maybe the table tennis table because I was playing in a club for a long time” [Transcript 33]) or transient part of the environment (“Honestly, I just remember all the dogs...and this is the park, like where the dog was” [Transcript 60]). Other reasons included using logic of turning direction (“I remember had to go right towards the pink houses. And here [*pointing at photo of tree-lined street]* I had to go left and I think it makes more sense right now” [Transcript 42]), or timing (“I remember the door because...I was so surprised because it was exactly in the moment that I passed it...it was perfect timing [Transcript 33]).

The results from Phase 2 are conflicting. On the one hand, there was little quantitative difference between the two groups in their route descriptions and performance on the landmark sequencing task. On the route descriptions, 60% (narrative) and 62.5% (landmark) of routes were rated as ‘good,’ though taken together with the ‘fair’ category, 87.5% (landmark) and 80% (narrative) of routes were able to get the listener heading

towards their destination with little or no additional assistance, a good result, given the difficulty of the task. The photo sequencing task showed good performance, with non-significant differences between the groups. On the other hand, data from the interviews shows that the narrative group additionally remembered information from the narrative, so it is not possible to conclude that the narrative did not lead to improved recall of the route shortly after navigating.

Additionally, both types of directions were well-received by participants, though the narrative group mentioned a slight adjustment period. Finally, the overall confidence for the photo task of both groups was high, supporting findings from Rehrl et al. (2010), who found that landmark directions resulted in high user confidence.

4.3 Phase 3: Route recognition and second photo sequencing test

After a period of one week, participants received a follow-up email which consisted of Phase 3 of the study. The online survey was broken down into two parts; a route recognition task (3a) and a second photo sequencing task (3b). The results of the two tasks from Phase 3 are presented in this section.

4.3.1 Phase 3a: Route recognition

Of the 12 questions asked, the narrative group performed slightly worse, with an average of 10.1 questions answered correctly. The landmark group averaged 11.4 questions correctly, a barely significant difference ($H = 3.918$, $p = 0.0478$, df = 1).

Because the task partly consisted of landmark sequencing, the survey asked participants about their confidence on a scale from one to five, with five being "extremely confident" and one being "not confident at all." However, because this task consisted of both landmark sequencing and route recognition, it is impossible to isolate the confidence to just landmark sequencing, so the result is not included in final conclusions about confidence in landmark sequencing.[2]

4.3.2 Phase 3b: Second photo sequencing test

Like the first photo test, a KWt between the four resulting groups confirmed that the average number of correct photo pairs showed non-significant differences ($H = 1.94$, $p = 0.585$, df = 3). Therefore, the two landmark groups were combined, as were the two narrative groups. Of the six photo pairs presented, the mean number of pairs eliciting correct responses was 5.88 (SD = 0.354) for the landmark condition and 5.60 (SD =

[2]Nevertheless, the results are reported here for transparency: the average answer was 4.12 (SD = 0.641) for the landmark group and 3.50 (SD = 1.080) for the narrative group, at a non-significant difference ($H = 1.735$, $p = 0.1877$, df = 1).

0.699) for the narrative condition. The difference is not significant ($H = 0.844$, $p = 0.3583$, df = 1).

Both groups showed the same average confidence in their answers for the photo task, with an average of 4.00 (landmark SD = 0.756, narrative SD = 0.816). Again, the scale was from one to five, with five being "extremely confident" and one being "not confident at all." This slight decrease in confidence compared to the levels reported in Phase 2b is expected given the one week delay between navigation and Phase 3b.

Memory of photo answers

While there was no difference between the groups in quantitative terms, some interesting answers arose in response to the question *"In general, how did you remember all of your photo answers? Did any information in the instructions help you remember your answers?"*. Some excerpts from the landmark group are provided below.

> **15** I think [it] is the combination of listening to the instructions, certain peculiar descriptions, and walking along the streets.
>
> **23** There are some conspicuous marks in each scene and that remind me the route when I saw the same mark in the pictures now. Even after one week, some marks are still very clear in my mind.
>
> **39** If I was given simply street names and directions which way to turn I probably would not have remembered any of the photos at all. If I were to walk the same path again, I would find my way without instructions. Had I used Google Maps or any other standard navigation system that would not be the case.
>
> **60** I think the most helpful part of the instructions was that they were very detailed and location specific instead of just „turn right/left". I remember some of the route we walked and the tree lined street because I forgot about that last week in the questions after walking.
>
> **95** Just like the machine learning algorithms, we're tested several times...the memory of those "correct" answers will be kept for a longer and longer time. For the first time, the instructions definitely help me to remember the answers, but this time, the tests last time are also very important, like half-half.

In general, the comments about memory of the second photo task can be categorized into memory of landmarks and learning effects from the tasks itself (repetition of the route in the tasks from the previous week). One user also mentioned that mistakes they made in navigation helped them to remember the sequences.

The narrative group showed similar patterns in their comments, but they also mentioned the narrative:

> **22** The instructions made me remember the sequence itself and I relate them with some of the remarkable elements in the path walked.

> **30** Yes, I think the fact of having a story behind the instructions helped me a lot. By remembering some important facts of the story which I associate with images I saw, it is easier to remember the order of facts even if there are some things that I don't remember.

> **50** The instructions definitely helped; Words such as 'he followed the WC sign' and 'he turned right at the veterinarian' have been deeply engraved in my mind!

> **70** Personally, some of the information I got during the survey one week ago were kind of engraved in my brain. Since the elements were seen by walking, heard from the headphones and then discussed with pictures it really helped to remember some without even trying to.

> **86** I was able to remember the points with reference to what was happening in the storyline [sic].

> **98** I remembered special things like the purple door, the toilet sign, the tree lane, etc. [be]cause I thought they had either funny or nice background information.

Similar to the landmark group, the narrative group also noted learning effects from the previous week and landmarks having an influence on their memory. Additionally, corresponding to their responses following the first photo task in Phase 2, the narrative group also brought up the narrative as a strategy for remembering the photo sequences.

4.4 General discussion

As with other research on spatial knowledge acquisition, this study implemented multiple methods to collect an overview of what information a user had retained about their environment. Novel in this research was the implementation of a mixed-method design, introducing interviews to attempt to better understand users' responses to both the route recall and photo sequencing tasks.

When assessed with quantitative methods, the overall results from Phase 2 and 3 show almost no difference in route memory between landmark and narrative instructions.

However, both groups performed generally well. In Phase 2a, almost all (83%) participants recalled routes that were rated as "good" or "fair", meaning that most parts of the route were discussed, and that the directions would generally lead a navigator to their goal. This is interesting given that the task was difficult for some participants, who noted that it would be far easier to re-walk the route. Participants in both groups recalled almost all photo pairs accurately in Phase 2b, and were similarly confident in their answers. In Phase 3, there were few quantitative differences between groups. Both groups were able to complete directions on a cued recall task with a high success rate, as well as select the next landmark with few errors. However, the landmark group performed slightly better on this task. In the second photo task, both groups also performed excellently.

Taken alone, the quantitative results would suggest that there is no difference between the two groups. However, the small sample size of this study somewhat weakens the validity of these quantitative results. Additionally, the narrative group possessed a slightly lower average SBSOD score and was more unfamiliar with the study area than the landmark group, which may have affected results. Furthermore, the general high scores from both groups, as well as little difference between the two could indicate the presence of a ceiling effect, that the tests were too easy. This may further be supported by the comments given by users in Phase 3b regarding learning effects, and should be carefully considered in future studies.

Finally, it is important to remember that landmark-based instructions like those used in the landmark control group have been proven to be more memorable than the metric turn-by-turn instructions being used in state-of-the-art navigation products (Denis et al., 2014; Löwen et al., 2019; Ross et al., 2004; Wunderlich & Gramann, 2021; Wunderlich et al., 2022). On the one hand, this is a further explanation for the lack of quantitative difference between the two groups, as well as an indication of the strength of landmark-based directions. On the other hand, the qualitative results from this study do show differences between the two test groups.

The qualitative data collected in this research provides more insight into the effect of narrative on route memory. In the interviews from Phase 2a, all participants in the narrative condition brought up the narrative while discussing the route. Sometimes users just referred to a narrative event or character as a descriptive or defining characteristic of a landmark, while other times users directly mentioned that it helped them to remember a part of the route.

This finding was also present in the qualitative results from phases 2b and 3b. When asked why they remembered a certain photo sequence, participants in both groups cited reasons such as the position of the landmark relative to the start or end of the route, uncertainty and mistakes, use of global landmarks, and slope. The narrative group, however, also relied on parts of the narrative to facilitate their memory of the sequences, with 9 of 10 participants citing the narrative at least once as a reason for remembering a sequence. When asked how they remembered their photo answers in Phase 3b, participants in the landmark group primarily cited landmarks and learning effects as reasons for memory.

The narrative group, on the other hand, additionally cited the narrative, with some mentioning landmarks and learning effects as other reasons.

Taken together, the results indicate that narrative instructions did not increase route memorability, with one caveat: the qualitative results indicate that it is not possible to conclude that the narrative did *not* have an effect. Participants did form some relationship to the narrative about Johann Strauss, which appeared in results from phases 2a, 2b, and 3b. This suggests that a narrative might act as an additional source of information that a navigator can rely on to remember landmark sequences along a route. Further research is necessary regarding exactly which components of a narrative are the most useful to the user and at which points in the route, however, that there was an effect is an important initial finding. Furthermore, the differences between quantitative and qualitative results suggest that narrative is not well-measured by quantitative methods, and a reconsideration of methodology is necessary to address the phenomenon observed in the qualitative data.

Finally, while this study did not set out to measure navigation performance, there was no observed difference in how participants in the narrative condition navigated the route in comparison with the control group. Participants in both groups reached the final destination with very few errors overall. This indicates that implementing a narrative into wayfinding instructions is entirely feasible. Furthermore, the enthusiasm and positive feedback about the instructions across both groups further encourage the development of landmark-based wayfinding instructions for pedestrians.

CHAPTER 5

Conclusion

Narratives are powerful tools for memory, from oral histories that pass down landscape knowledge, to successful mnemonic devices (Baddeley, 1999; Livo, 2018). Narratives are good memory devices because they organize incoming information, and provide additional imagery that humans can incorporate into their already existing knowledge (Baddeley, 1999; Crowley, 2018; Reisberg, 2010).

Meanwhile, in the last decade, navigation systems designers have turned towards more human-centered approaches. Of particular interest has been how to develop digital mobile systems that support instead of hindering spatial knowledge acquisition, which includes the ability to remember a route. While narratives have been incorporated into maps in different ways, it has not yet been explored whether narratives can be implemented in wayfinding as a memory aid.

The objective of this research was to identify whether the augmentation of verbal route instructions with a narrative can be used to increase the memorability of a route to pedestrians. By designing narrative instructions and testing them in a user study, this overall research objective was met. The research objective was targeted using two primary research questions and three sub-questions, the outcomes of which are addressed below.

RQ 1.

First, it was necessary to determine how narratives are created. Based on a review of the literature in narratology, the principal components, that is, the necessary 'base units' of narrative were identified in Section 2.3. Some principal components could be already identified in state-of-the-art metric instructions, primarily that directions are already actions which take place in a setting, sequenced to provide meaning to a user, and communicated in some way. This allowed for the design of the narrative for this study to focus on introducing strong causal relationships between story events, which were tied to landmarks in the physical environment (see Section 3.1.1).

RQ 2.

In order to address the second research question, *Does augmenting navigation instructions with a narrative increase the memorability of a route?* the question was broken down into three sub-questions:

RQ 2.1. The quantitative results addressing RQ 2.1 showed that immediately after navigating and one week later, there were only slightly significant differences on the users' recall of the route compared with the landmark control group. This was measured in Phase 2a by asking users to verbally describe the route (where where the groups performed comparably), as well as one week later in Phase 3a, where users needed to select the correct turning direction on the route and select the following landmark. Only Phase 3a showed a slightly significant difference between the two groups, with the landmark group outperforming the narrative group ($H = 3.918$, $p = 0.0478$, df $= 1$). Interestingly, in interviews during Phase 2a, all participants in the narrative group referred to narrative events, whether as an additional attribute of the landmark, or specifically as an anchor that helped them remember a landmark.

RQ 2.2. The quantitative results addressing RQ 2.2 show no difference between the narrative and landmark control groups in terms of memory of landmark sequence. This was measured in phases 2b and 3b with paired photo sequencing tasks. However, in the qualitative data, participants very clearly name the narrative as a strategy for remembering photo pairs, among other strategies such as relative position of the landmark, uncertainty, and slope in Phase 2b, and learning effects and the presence of landmarks in the directions in Phase 3b.

RQ 2.3. User confidence for the photo sequencing tasks was similar in each group, both shortly after navigating and one week later. To measure confidence in landmark sequencing tasks, phases 2b and 3b included the 5-point Likert scale question *On a scale from one to five, how confident are you in your photo answers?* Results between the groups showed non-significant differences. Confidence was not specifically addressed during qualitative data collection, but the positive reception of both types of directions indicates that users enjoyed navigating with the directions.

In response to RQ 2, the quantitative results show that the incorporation of this narrative did not lead to improved memorability compared with landmark-based directions. On the other hand, the qualitative results from this study do not support this result, and suggest that narrative may have an effect on users' memories of the route. Taken together, the results suggest that there is more room to explore narrative in wayfinding, but that the phenomenon may not be well-measured by quantitative methods. Furthermore, the general positive reception of both narrative and landmark-based directions is encouraging for further research.

5.1 Limitations

While this research provides an interesting first step in exploring narration as a tool for wayfinding, it has a number of limitations.

As mentioned before, the results of this study are likely influenced by small participant numbers (N = 18). This was most apparent when comparing the two groups, with n = 8 and n = 10 participants. However, some other studies had similar numbers of participants (e.g. Anacta, Li, Löwen, Galvao & Schwering, 2018; Anacta et al., 2017; Huang et al., 2012). One unexpected benefit of this smaller sample size was that it was easier to rate the quality of the route for one researcher, as it allowed direct comparison between routes to ensure consistency. The rating of routes by only one researcher is uncommon in the literature, where route depictions (verbal or sketch) are usually rated by two or three researchers, ensuring consistency (e.g. Anacta et al., 2017; Denis et al., 2014; Krukar et al., 2020). This research would benefit from two or three raters to ensure consistency of results. Finally, transcripts were semi-blinded; only the participant number was available to the researcher, not which condition the participant was in. Nevertheless, the researcher was sometimes unintentionally aware of the condition due to previous work with the transcripts, which may have affected results.

Additionally, time constraints (both on the researcher side for data processing as well as the participant side for recruitment) limited both the type and number of questions that could be asked during the research. For example, the online survey developed for Phase 3 consisted mostly of close-ended questions, to ease data processing for that phase. Phase 3a included a cued-recall task instead of free recall of the route like Phase 2a. In Phase 3b, participants were not asked why they remembered each photo sequence after each pair like they were in Phase 2b, but were asked after all photos had been sequenced how they, in general, remembered the pairs.

Much of the existing research on incidental knowledge acquisition of a new environment focuses on overall spatial knowledge acquisition, that is, tasks are usually designed to assess landmark, route, and survey knowledge. This means that studies often employ a range of methods to measure these three types of knowledge both individually and in conjunction with each other. To narrow the scope of this research, the memory of route knowledge was the focus. However, determining which methods are appropriate for measuring route memorability from the literature is difficult, because of the typical broad focus on spatial knowledge acquisition. This study relied heavily on methods used in Daniel et al. (2007) and Denis et al. (2014), who specifically studied route memorability. The methods were cross-referenced with other studies, targeting the methods from these studies which were specific to route knowledge (see Section 3.1). Nevertheless, to assess what part of navigation instructions were remembered, is was deemed important to add a semi-structured interview and open-ended questions to the methods so that the user might explain their choices.

This mixed-method design is a novel method for assessing route memorability. Furthermore, the method was useful as it gave the researcher more information in cases of

ambiguity in rating the route directions, and gave the participant the opportunity to correct or add any additional information that came to mind immediately after describing the route, ultimately giving a more wholesome representation of their memory of the route. Discussion mostly centered on *why* a participant did or did not remember particular route segments or landmarks, but questions about the actual route also came up. Great care was taken to avoid re-telling the route to the participant by instead prompting the participant to fill in any blanks in their route memory on their own. However, discussing these themes may have lead to some learning effects, which are critical to manage in a study focused on memory. Finally, including a semi-structured interview and open-ended questions can produce a lot of data, especially if the structure is not carefully considered. The participants in this study were very engaged and keen to share their ideas, resulting in a lot of data. It is recommended to have an experienced interviewer following targeted questions to conduct this part of the research in the future.

5.2 Implications for further research

The research conducted in this thesis is just a starting point for exploring the effects of narrative in wayfinding. Specific to this thesis, the rich data set that was produced during this study has the potential to provide answers to a number of interesting questions which were not addressed in this research. It was not investigated, for example, whether people who with a poor SOD performed as well as those with a good SOD on the tasks within each group. This may be interesting, especially given that people with a good SOD tend to use survey knowledge, while those with a poorer SOD tend to rely more on route knowledge (Ishikawa, 2019).

Additionally, of methodological interest is how a reconsideration of the methods used in this study may better approach the phenomenon under study. One example could be changing the way the verbal recall of a route is prompted (i.e. a different initial question instead of the 'lost key' scenario). For example, users could be asked to repeat the directions to a friend so that the friend can easily memorize the route. This might give researchers a better idea of which information users' find valuable for memory.

Furthermore, this study relied on landmark-based route instructions as a control, given the existing research about their impact on memory. However, further research could investigate the layering of a narrative onto state-of-the-art metric instructions to get a better sense on the overall impact of the narrative.

More broadly, the research opens up pathways for further exploration of the topic. The research took a first attempt at designing narrative instructions for wayfinding, and testing the effects on memorability of the route. The instructions designed for this study implemented an overarching narrative that connected the first event to the last, stressing explicit causal relationships between events. This is not the only way to incorporate narrative, and represents one designer's first attempt. Narratology is a broad field, and there are likely other interpretations on the definition of narrative available from which designers can draw from. The development of narrative instructions in this thesis is not

the only way to incorporate narrative into wayfinding instructions; nor is it necessarily the best. It is simply offered as one approach to the topic. Other approaches such as layering short narratives onto each landmark individually may be entirely suitable for navigation instructions and have different effects on memory, suggesting a further research direction. Overall, narrative can be incorporated into wayfinding directions, but the question still remains open as to whether it leads to improved memory of a route.

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Appendix A: Recruitment and communication materials

This appendix can be accessed at: Appendix A

Appendix B: Landmark photos

This appendix can be accessed at: Appendix B

Appendix C: User study materials

This appendix can be accessed at: Appendix C

Appendix D: Transcripts

This appendix can be accessed at: Appendix D