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Paired social wayfinding: Dyadic interaction in real-world navigation

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Paired social wayfinding: Dyadic interaction in real-world navigation

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Doctor of Philosophy
in
Geography

by

Crystal Ji-Hye Bae

Committee in charge:

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September 2020

The Dissertation of Crystal Ji-Hye Bae is approved.

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June 2020

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Curriculum Vitæ

Crystal Ji-Hye Bae

Education

2020	Ph.D. in Geography (Expected) with an emphasis in Cognitive Science, University of California, Santa Barbara. Dissertation: "Paired Social Wayfinding: Dyadic Interaction in Real-World Navigation". Committee: Daniel R. Montello (Chair), Mary Hegarty, Geoffrey Raymond.
2015	M.A. in Geography, University of California, Santa Barbara. Thesis: "Representations of an Urban Neighborhood: Residents' Cognitive Boundaries of Koreatown, Los Angeles". Committee: Daniel R. Montello (Chair), Helen Couclelis, Konstadinos Goulias.
2010	B.A. in English Literature with a Minor in Geographical Information Science (GIS), The George Washington University, Washington, DC. Graduated *Magna Cum Laude*.

Publications

Bae, C. J. & Montello, D. R. (2019). Dyadic route planning and navigation in collaborative wayfinding. In S. Timpf, C. Schlieder, M. Kattenbeck, B. Ludwig & K. Stewart (Eds.), *14th International Conference on Spatial Information Theory (COSIT 2019)*, Leibniz International Proceedings in Informatics (LIPIcs), Vol. 142 (pp. 24:1–24:20). Dagstuhl, Germany: Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik. doi: 10.4230/LIPIcs.COSIT.2019.24

Bae, C. J. (2019). Structures of route suggestions in navigational planning. In K. Stock, C. B. Jones & T. Tenbrink (Eds.), *Speaking of Location 2019: Communicating about Space*. Regensburg, Germany, September 2019.

Bae, C. J. & Montello, D. R. (2018). Representations of an urban neighborhood: Residents' cognitive boundaries of Koreatown, Los Angeles. *Built Environment*, 44(2): 218–240. Alexandrine Press. doi: 10.2148/benv.44.2.218

Fellowships and Awards

2020	Early Career Collaboration Enhancement Award from Diverse Intelligences, Collaborative project with H. Davis, K. Mayer, & O. Mattias, $5,000
2019 to 2020	UCSB Graduate Opportunity Fellowship, Central Campus Fellowship (university-wide competition), Tuition, fees, & stipend

2019	Diverse Intelligences Summer Institute (DISI) Fellowship, University of St Andrews, Scotland, $3,400 honorarium provided
2019	AAG Specialty Group Travel Award, Environmental Perception and Behavioral Geography Specialty Group, $100
2017 to 2020	The Jack and Laura Dangermond Travel Award, UCSB Department of Geography, $4,000 total
2017	Doctoral Student Travel Grant from the UCSB Academic Senate, $1,350
2014	University of California Transportation Center (UCTC) Fellowship, $10,000

Conference Presentations

2020	"Comparisons of Dyadic Leadership during Navigation" at the American Association of Geographers (AAG) Annual Meeting in Denver, CO (in-person meeting cancelled)
2019	"Dyadic Route Planning and Navigation in Collaborative Wayfinding" (full paper) and "Suggestion Sequences during Route Planning" (workshop paper) at the Conference on Spatial Information Theory (COSIT) in Regensburg, Germany
2019	"Characterizing Spatial and Social Strategies during Collaborative Situated Navigation" at the American Association of Geographers (AAG) Annual Meeting in Washington DC
2018	"Route Planning and Situated Navigation in a Collaborative Wayfinding Task" at Spatial Cognition in Tübingen, Germany
2018	"Collaborative Route Planning and Navigation in a Novel Environment" at the Interdisciplinary Navigation Symposium (iNAV) in Mont Tremblant, Canada
2017	"Paired Social Wayfinding: Dyadic Interaction in Coordinating Real-World Navigation Behavior" at the Conference on Spatial Information Theory (COSIT) in L'Aquila, Italy

Poster Sessions

2018	"Route Planning and Situated Navigation in a Collaborative Wayfinding Task" at Spatial Cognition in Tübingen, Germany
2018	"Route Planning and Situated Navigation in Collaborative Wayfinding" at spatial@ucsb.local in Santa Barbara, CA
2015	"Neighborhood Boundary Representations: Koreatown, Los Angeles" at spatial@ucsb.local in Santa Barbara, CA

Invited Talks

September 2019	Panelist for Experienced TA Panel at the UCSB TA Orientation
April 2018	Speaker at Language, Interaction, and Social Organization Seminar: "Collaborative Route Planning and Situated Navigation in a New Environment"
November 2014	Speaker at UCSB Geography Department Colloquium: "Representations of the Urban Neighborhood: Residents' Cognitive Boundaries of Koreatown, Los Angeles"

Teaching

Teaching Certifications and Awards

Winter 2020	Certificate in College and University Teaching (CCUT)
Spring 2016	UCSB Department of Geography Excellence in Teaching Award
Summer 2015	Summer Teaching Institute for Associates (STIA) Certificate

Teaching Associate (Instructor of Record)

Fall 2016	GEOG 108: Urban Geography. Upper-division course on the structure and development of cities and their regions.
Fall 2015	GEOG 5: People, Places, and Environment. Survey course covering fundamental concepts of human geography.
Summer 2015	GEOG 153A: Behavioral Geography Upper-division course in behavioral and cognitive geography.

Teaching Assistant

2018	GEOG W12: Maps and Spatial Reasoning
2014, 2016, 2018	GEOG 117: Scientific Research Methods in Geography
2014, 2018	GEOG 108: Urban Geography
2013, 2017	GEOG 5: People, Places, and Environment
2015, 2016	GEOG 150: Geography of the United States
2015	GEOG 153C: Environmental Perception and Cognition
2014	GEOG 176B: Technical Issues in Geographic Information Systems

Employment

Program Manager for the UCSB Cognitive Science Program (2016–2020)
Served as main point of communication for affiliated faculty and participating students in the Cognitive Science Interdisciplinary Ph.D. emphasis. Hosted events, maintained mailing lists, and regularly updated the official Cognitive Science website.

Research Associate for the Collective Spatial Cognition Project (2018–2019)
Co-organized a specialist meeting on Collective Spatial Cognition in April 2019 in Santa Barbara, with funding from a multi-university grant from the U.S. Army Research Institute for the Behavioral and Social Sciences, shared between UCSB Geography and the University of Alabama Laboratory for Location Science.

Program Facilitator for the UCSB Summer Teaching Institute for Associates (STIA) (2018–2019)
Prepared graduate students for their first time teaching as instructors of record by hosting workshops, seminars, and providing additional mentorship in various aspects of teaching at the university level.

Research Associate at the UCSB Center for Spatial Studies (2015–2018)
Regularly scheduled and hosted events affiliated with the Center for Spatial Studies, including Spatial Tech Lunches and Lightning Talks. Maintained listserv and web communications across campus departments and community members.

Service and Community

Research Mentorship

- Directly supervised 11 undergraduate research assistants (2014–2020).
- Nominated and served as UCSB Graduate Scholars Program (GSP) Mentor to three early graduate students (2019–2020).
- Mentored two high school students in the UCSB Research Mentorship Program (Summer 2016).

Professional Service

- Organizing committee for the Collective Spatial Cognition specialist meeting, jointly hosted by UCSB & University of Alabama (2018–2019).
- Graduate student volunteer for UCSB Center for Spatial Studies specialist meetings (2016–2018), including 'Universals and Variation in Spatial Referencing across Cultures and Languages'.
- Graduate student representative to the UCSB Geography hiring search committee for Assistant Professor in Spatial, Environmental, and Geographic Cognition (2015–2016).
- Geography department representative to the UCSB Graduate Student Association (2014–2016).
- Organizing committee for the UCCONNECT Student Transportation Conference (2014–2015).

Professional Memberships and Affiliations

- Cognitive Science Society (CSS)
- 500 Women Scientists, Santa Barbara Chapter
- Spatial Intelligence & Learning Center (SILC) Research Network
- Cognitive Navigation (CogNav) Research Group
- Language, Interaction, and Social Organization (LISO) Research Group
- American Association of Geographers (AAG)

Technical and Analytic Skills

- Geographic Information Systems (GIS): ArcGIS Desktop and Online, OpenStreetMap, MapBox, GPS field data collection
- Programming & Statistics: R, Python, SPSS, STATA, MATLAB, HTML/CSS
- Qualitative Analysis: Survey design, Conversation Analysis, transcription and coding
- Design: Video recording and editing, Adobe Creative Suite (Photoshop, Illustrator, Premiere Pro)

Abstract

Paired social wayfinding: Dyadic interaction in real-world navigation

by

Crystal Ji-Hye Bae

The cognitive process of wayfinding is necessarily situated in a social world, whether someone is traveling with another person to a shared destination or interpreting the physical traces of others' activities to direct their travel. Wayfinding involves integrating multiple sources of information about the environment, one of which is the direct or indirect influence of the social context. The presented work expands our understanding of human navigation as it unfolds in a social context. I investigate pedestrian navigation by pairs of people (both stranger dyads and friend dyads) as well as individuals in an unfamiliar, real-world environment. In three studies, participants were asked to plan and enact a route between a given origin and destination. Each dyad or individual first devised a route using a map of the environment, then was taken to the environment and asked to navigate to the destination from memory alone. I video-recorded participants during both planning and navigation, using Conversation Analysis (CA) for the evaluation of social interaction. The complexity of human behavior in groups calls for such interdisciplinary methods of inquiry and approaches to understanding.

With these studies I examine explanations for successful route planning, spatial and social strategies employed during wayfinding, and sources of uncertainty in navigation. This includes differences between situated and prospective planning—participants often collaboratively adapt their route-following on the fly based on unexpected challenges. This research contributes to the understanding of how people encode and coordinate their spatial knowledge to solve the important problem of navigating through the environment.

It has further implications for the design of navigation aids, expanding what we know about the practices of multiple people working in conjunction on a wayfinding task.

Contents

Chapter 1

Introduction

1.1 Project Context

The cognitive process of wayfinding is necessarily situated in a social world, whether someone is explicitly traveling with another person to a shared destination, following route directions from a local resident, or using the influence of physical traces of others to direct their travel. Wayfinding involves integrating multiple sources of information about the environment to travel to a goal location, and the direct or indirect influence of the social context is an important one of these sources. However, the amount of research attention given to social aspects of wayfinding and navigation is paltry compared to that given to the study of the individual wayfinder. My master's work explored the physical and social setting that contributed to residents' spatial cognition of urban neighborhood boundaries, taking as my study site the neighborhood of Koreatown in Los Angeles. The situated real-world study of how people represent such a region in their minds – and the multitudinous influences acting upon those representations – pointed my attention to the complexity of the social environments within which we conduct our lives. For my Ph.D. work, I direct my inquiry into the direct social interactions at play while people collaborate in real-world wayfinding tasks. The two main studies described here explore route planning and situated navigation for dyadic partners, both without prior familiarity with one another and those with a prior relationship.

Wayfinding is a complex and multifaceted act that depends on our mental representations of physical environmental spaces that we experience directly or indirectly [1]; in many cases, we learn environments both directly, by traveling through the environment, and indirectly, via symbolic media such as maps or language. Both the planning and enactment of a route through navigation are important wayfinding processes that are often social. We may more often travel in groups of various sizes than solo. Analyzing navigation behavior "in the wild" [2] within a more realistic social setting, versus in a controlled laboratory or virtual setting, is important for the construct and ecological validity of this work. While a wealth of information informs our understanding of wayfinding on an individual basis, a small but growing body of work forms the basis for our knowledge about social interaction in human wayfinding and navigation.

1.1.1 Role of Spatial Cognition in Navigation

The field of spatial cognition covers a broad array of subjects related to how people perceive, understand, remember, and learn spaces, ranging from the scale of small, table-top spaces to the environmental scale spaces that surround them [3]. Spatial cognition is focused on how we develop and use our mental representations of space, and in my research I am especially interested in how this affects peoples' route planning and navigation behavior. Many researchers in the area of spatial cognition have investigated wayfinding and navigation behavior – how it is that people can make their way through a large-scale physical environment to a specified goal location. These researchers hail from disciplinary traditions such as geography, psychology, cognitive science, and others, with increasing attention from sociologists, linguists, and computer scientists.

Wayfinding is a process that consists of all the acts associated with planning the way between an origin and a destination, including recognizing landmarks, remembering routes, and orienting oneself within the environment. This critically depends on our mental representations of physical environmental spaces (referred to as our *spatial representations*). Navigation is the act of wayfinding together with locomotion, which is the act of physically coordinating one's body to move within the environment in question to carry out the wayfinding task [1]. Locomotion in navigation is important because of the sensory modalities that contribute spatial information essential for finding one's way. For instance, in navigation through virtual environments, we do not have the same level of feedback from our sensory systems, such as our vestibular or kinesthetic senses, which help us estimate the distance traveled, radius of turning, and speed in physical, real-world navigation. Virtual environments therefore may provide additional challenges for human navigation. Along with locomotion, there are higher-order cognitive processes that help us plan and direct our movement towards a destination. In the Background chapter, I elaborate further on the research in spatial cognition relevant to human navigation.

1.1.2 Behavioral Approach to Geography

The "behavioral" approach to geography, like most other approaches in human geography research, is concerned with human behavior. This approach understands people as active information-gatherers and -processors who make choices by weighing alternatives against their states of knowledge and held beliefs. Within geography, the behavioral approach has been present in its contemporary form since at least the 1960s [4]. However, it may be more accurately termed a *cognitive* approach to geography due to its focus on the cognitive processes that mediate the behaviors observed. The topics of inquiry in behavioral geography are not new to the discipline, as subjects such as environmental perception and human-environment interactions have been around since as long as the early 20th century (for instance by Gulliver in 1908 [5] and Trowbridge in 1913 [6], both described in the next chapter).

The behavioral approach to geography developed in opposition to ideas presented by classical economic theory, cultural geographic beliefs about environmental determinism, and the ideas of social physics such as gravity models [7]. The ideas of classical economic geography rested upon simplifying assumptions that ignored important aspects of human spatial decision-making. For instance, in everyday temporary travel a person may generally seek to minimize distance, and this decision process is likely based on their incomplete or inaccurate knowledge of the environment, which is largely ignored by economic geographers. Behavioral geographers also responded to ideas about environmental determinism by calling for a more sophisticated understanding of the human-environment relationship; namely that cognition serves to mediate between external environmental influences and observable human behavior. Gravity models of behavior similarly failed to recognize the essential role of cognition, instead treating people as masses (aggregate groups) acted upon by outside forces, with their actions dictated by physical attributes of the environment such as town sizes and distances.

The responses to these ideas point to the four main characteristics of the behavioral approach in geography. The first is the micro-level or disaggregate level of analysis. The individual is treated as the scale of analysis – behavioral geographers are interested in the patterns and processes at the individual level, rather than at an aggregate or group category level. This first characteristic is central to the others and distinguishes behavioral geography from most other geographic research approaches. Historically, analysis of human behavior in geography has been studied on an aggregate level, such as at the scale of the Census tract or social group.

Second, behavior is based on the subjective world, which may not be consistent with the objective world. People do not act based on the objective world, but on what they know or think about it. This differs, for instance, from classical economic geography approaches, which assume that people exhibit economically rational behavior based on perfect and complete knowledge. A behavioral geography approach to understanding spatial choice and decision-making processes in residential relocation, on the other hand, would not only be interested in the alternatives available to a person and their relative costs, but how the entire set of alternatives is based on their personal knowledge, preferences, goals, memories, and societal and cultural contexts. The value of a single alternative is not defined by a simple utility function, but by a probabilistic expected utility function. Not only are people uncertain about the outcomes of their decisions, they have incomplete knowledge about what would hold the best outcome for them, and even define "best" differently based on their individual preferences and goals.

Next, the individual and the environment exist in a bidirectional relationship. The external environment influences human behavior through cognitive processes that dictate what a person attends to, learns, remembers, and cares about [4]. Correspondingly, what is attended to in the environment depends on the individual's own prior experiences, knowledge, preferences, and so on. The individual has a specific knowledge base based on his or her experience of the environment, and his or her own way of knowing is couched within a political, social, and cultural context. Therefore, it is too simplistic when studying human spatial behavior to ignore either the internal or external influences acting on a decision process.

The fourth characteristic of the behavioral approach is that it is multidisciplinary and interdisciplinary. Though this can also be said of geography more broadly, behavioral geography importantly rests on both concepts and methods drawn from psychology (including environmental, cognitive, social, and development psychology), sociology, planning and architecture, economics, and anthropology. This is in part due to its development around the same time as environmental psychology, as seen in publications and academic journals such as *Environment and Behavior*, established in 1969. No other single subfield in geography can be said to be as multitudinous as behavioral geography. In this project, I employ disciplinary approaches from geography as well as psychology, sociology, and cognitive science more broadly.

The four main characteristics of behavioral geography also situate it as a more systematic approach within the discipline of geography. The historical shifts within geography at large speak to its versatility and its wide reach as a discipline, and geographers from at least as far back as the early 20th century have grappled with questions relating the individual to his or her environment. The National Research Council report on geography's future in 1997 emphasized the importance of "integration in place" by systematically investigating the dynamics of environment and society, with greater interaction between disciplines outside of geography [8]. Behavioral geography deals with important facets of the link between human behavior and the environment, drawing from related work across disciplines, and this lends strength to the discipline of geography and its search for meaning. Geography includes work done at not only the macro-scale of aggregated groups but also at the micro-level of the individual and in-between [4]. It is lent much credibility by doing so not only in a humanistic way, but increasingly in a more systematic and integrative way.

The approaches and techniques of behavioral geography are still missing in many academic geography departments today and are often relegated to specialized journals in other disciplines. Part of the reason for this is that behavioral geography work is highly interdisciplinary, drawing on behavioral study methodologies and analytic techniques from psychology (as the unit of focus is the individual) that are only occasionally applied within geography's other sub-fields. However, this is a changing trend, with more advanced degrees being awarded in these topic areas. More fields of research today are seeing the benefit of interdisciplinary communication, and academia should continue to cultivate this conversation across disciplines. With its fairly recent emergence, it is only a matter of time before the behavioral or cognitive approach comes to be represented in a greater number of geography departments and finds a place in nearly all applied geographic questions.

Approaches to answering these big questions in behavioral geography, such as how people learn, remember, and find their way through the physical environment, are strengthened by the increasing interest and efforts in interdisciplinary approaches. Cognitive studies bring together disciplines formerly separated by disciplinary boundaries like experimental psychology and humanistic approaches to tackle these questions of cognition from multiple vantage points. For understanding how groups of people plan routes and navigate in environmental scale spaces, it is necessary to integrate these perspectives and ways of knowing.

1.1.3 Route Planning

Route planning is the first phase of most navigation tasks, prospectively determining how to best find one's way between an origin and destination. When communicating a route plan to others, people commonly give directions by providing a sequentially-structured set of instructions used to identify a route from an origin to a destination [9]. Investigations into direction-giving allow us to define the structure of a complete set of route instructions, what is at the core of a route plan, and what makes for more or less effective route directions [10, 11, 12]. The establishment of common ground discussed in the route directions literature is also important to people working together in planning and in active navigation. Planning is a complex set of cognitive processes that involves the use of what is known and also what is uncertain, and planning by multiple people working together becomes more complex by introducing communication and information-sharing processes. Observing plans, and the ongoing process of planning itself, gives us an important window into the processes related to purposeful action in human behavior [13].

Specific to the context of wayfinding, studies by Hölscher et al. [14] show a profound difference between situated and prospective planning, wherein participants often modify their route-following *in situ*. The authors also highlight differences between the construction of routes for oneself and for others: Effective routes planned for others are simple (with few direction changes) and contain distinctive landmarks; those planned for oneself are attractive, fast, direct, and not too busy. Additionally, route plans intended for others include more detailed descriptions to establish common ground between planner and addressee. This suggests that verbalized plans of intended behavior often differ from real-world behavior, highlighting a need for more situated studies. My work looks at these behaviors in planning and during real-time navigation with a partner.

1.1.4 Navigation

Navigation along a route, as opposed to only planning a route, presents contextual challenges of remembering the route plan, understanding correspondence of the plan to the experienced physical environment, self-localizing and maintaining one's orientation, judging distances, and (often) coordinating one's spatial knowledge with others. Spatial disorientation and misorientation are common problems threatening any navigation activity. According to Montello [15], geographic *disorientation* occurs when people believe they are unsure of their location or heading or which way to go to reach a destination (what people mean by explicitly expressing they "are lost"). When people are geographically *misoriented*, in contrast, they are objectively not where they think they are or are not going the correct way towards the destination, regardless of their awareness. People rely on their own spatial cognitive abilities to confront these challenges in navigation.

Environmental factors like low visibility, poor signage, and outdated maps often present real-world challenges to orientation and wayfinding. Fortunately, people have many available strategies to overcome being lost, such as moving in a specific direction, sampling routes from a location, and backtracking [16]. However, the way individuals employ these strategies may only partially inform strategies at the group level. For groups, the presence of social factors could either cause problems like disagreement between navigational partners, or could provide valuable aid in dealing with unexpected problems. I look here at wayfinding challenges as well as strategies enacted by people at the dyad level.

1.1.5 Group Navigation

For this research undertaking it is crucial to study how people spatially reason, plan, and act in real-world environments in particular. Analyzing how these processes occur "in the wild" versus in a controlled laboratory setting is important in adding validity to our research, and along these lines, it is therefore essential to study spatial cognition as it occurs in a realistic social context [2]. The environments in which we think and act are inherently social, as we cannot readily escape the influences of others who have come before us, who have taught us to find our way and read our surroundings, and who directly impact our decision-making. It is of little debate that much real-world human navigation is performed by more than one individual rather than in isolation. As social beings, we are often accompanied by others when we travel between places and we work out the tasks of finding places together. Navigation involves the integration of multiple sources of information about the environment, one of which is the direct or indirect influence of the social context. However, navigation as a social process has been relatively ignored in the spatial cognition literature, where most of this research is undertaken.

There is recent enthusiasm around the social dimensions of wayfinding [17], though not traditionally explored by spatial cognition researchers. One distinctive example was Hutchins' work on "cognition in the wild," [2] which studied the navigation of a U.S. Naval crew as socially-distributed cognition, situated in the real world, rather than as an independent mental act. Hutchins proposed that group cognition in humans may have qualitatively different properties than individual cognition. This provides support for the ecological validity of conducting such a study in the real-world versus in a lab or virtual environment.

One important finding from He et al. [18] is that better navigators appear to adjust their route directions to the navigational ability of their partner. In their study on route direction-giving and -receiving by pairs (using mobile phones for communication), they found that participants with a better sense of direction were better equipped to adjust how they provided navigational instructions. They were able to do so both because they stored more information about the environment they had traversed, and because they were more attuned to their partner's informational needs. Their study shows that flexibility in social coordination between members of a dyad may help overcome the disadvantages of being a poor individual navigator. Pairs perform differently than individuals not only due to differences in their spatial abilities but also because of their interpersonal route communication. Our work builds on this using pairs of people working synchronously in a wayfinding task to explore how people communicate when navigating together, and compares this to solo performance on the same task.

These studies examine the *dyad* as the unit of analysis, a pair of individuals who work together toward a shared goal. The dyad is considered the simplest-sized social group. Simmel's work on social geometry states that as each individual person is added to a group, different social behavioral dynamics emerge, such as a triad's tendency to act more as a dyad plus an individual, and a four-person group to divide into two dyads [19]. Specific to dyads, Reilly et al. [20] characterized the social roles adopted within pairs during navigation. These roles include, but are not limited to, roles such as leader and follower, or independent versus collaborative participants. I use this as a starting point to look at differences in how dyads act more or less collaboratively during both planning and navigation.

1.1.6 Social Interaction Analysis

Social interaction and communication are essential to the behavior of groups. The close investigation of social interaction that we employ in this project is *Conversation Analysis* (CA). A key feature of this approach [21, 22, 23] is its concern with conversational talk as it unfolds within a socially-shared context. CA as applied to situated navigation gives us methods of understanding how the project of wayfinding is constructed and maintained in real time (e.g. [24]). When multiple people navigate together, they must orient themselves with regards to the physical environment as well as coordinate their spatial knowledge to establish a shared reality within which they can work [25].

Many behavioral studies are predesigned to record certain expected behaviors, wherein the topics of observation are determined beforehand (i.e., they are top-down). On the other hand, CA gives us a bottom-up opportunity to learn the strategies people employ to form common ground, for example using place labels to establish shared understanding [26]. By examining the talk immediately following an action, we observe how participants jointly understand and respond to what is being done. In the case of navigation, a person may see their partner pause at a juncture and use that opening to provide instruction.

We can see that they understand the pause as an expression of uncertainty and as a point of potential intervention. People clearly orient themselves not only to the spatial task of navigation but also to the social task of shared understanding.

In these studies, I demonstrate the value of incorporating the methods of CA to understand social actions and strategies relevant to wayfinding. By observing both route planning and in-person navigation, I compare how navigational plans are proposed ahead of time (prospectively) to how they are enacted in the physical environment (situatively). Close analysis of navigational performance by different dyads helps us explain how social interaction contributes to success or failure in solving wayfinding problems such as recovering from being lost. In particular, I focus on the issues of leadership, knowledge alignment and uncertainty, and individual characteristics.

1.2 Research Contributions and Questions

In my research, I explore social coordination in paired wayfinding, particularly in the case of pairs of people (*dyads*) working directly and synchronously with a partner to find their way to a goal location. Though geographers, sociologists, psychologists, and other researchers have not traditionally explored the social dimensions of wayfinding behavior, there is a more recent influx of enthusiasm around the topic [24, 18]. This research contributes to the understanding of how people align pre-existing knowledge with others to solve the important problem of navigating through the environment. It has further implications for the design of both physical and digital navigation aids, expanding what we know about the information needs of multiple people working in conjunction on a wayfinding task.

Although dyads will be used as the unit of analysis, future work should additionally consider triads and larger groups to explore other relevant effects of group size. The social behavior of triads and larger groups is expected to substantially differ from that of dyads [19]. These added complexities make it necessary to limit this line of inquiry to the simplest social group. Measures based on the individual participants will also be included. This research straddles the line between the methodological traditions of geography and sociology, which generally apply group-level analyses, and psychology, which conventionally examines the individual.

1.2.1 Research Questions

My research questions are as follows:

1. How do dyads work together to plan navigational routes through a novel environment?
   (a) What characterizes prospective paired planning versus situated (*in-situ*) paired planning of a route?
   (b) How do route planning strategies differ based on individual differences in spatial ability, for instance as self-reported through existing sense of direction (SOD) measures?
2. How do dyads coordinate their knowledge and behavior in a real-world spatial navigation task?
   (a) How efficient are different pairs of people in their navigation task performance, in terms of time and distance minimization? Which social interactive factors contribute to this performance?
   (b) How, when, and to what end are leadership and following roles adopted within the dyadic interaction? How does this differ between strangers and friends?

   (c) How and when do individuals communicate trouble to their wayfinding partner, including social trouble (such as disagreement, confusion, or indecision) or wayfinding uncertainty?

3. How do individuals behave and perform differently on this task as compared with dyads?
   (a) Do individuals perform better or worse on planning and navigation tasks than do stranger or friend dyads? What factors contribute to this difference, if any?
   (b) How well does a think-aloud protocol allow the assessment of individuals' wayfinding strategies during real world navigation?

1.2.2 Contributions of this Project

This research agenda furthers our understanding of social interaction in the context of wayfinding in several significant ways. First, using behavioral studies of pairs of people planning routes, I characterize the ways in which people coordinate shared knowledge of an environmental context and formulate an effective navigational plan in conversation. I also compare how this navigational plan is proposed ahead of time (prospectively) to how it is enacted in the physical environment (situatively). I demonstrate here the value of Conversation Analysis for understanding common social actions and strategies in route planning. For instance, if leadership roles or spatial competence is established at this early phase, how is that carried into the execution of the navigation task?

Then, using the results from both the route planning and route execution phases, I formulate a generalized framework for dealing with common problems in navigation, focusing on the role of the route plan as executed *in situ* by the participants. This analysis is informed by prior work in individual and group route planning and execution, including work by Allen [10], Denis, Pazzaglia, Cornoldi, & Bertolo [11], and others.

I outline specific social roles taken by participants in these paired groups, taking as a starting point the characterizations of wayfinding roles previously proposed by scholars [20]. These potentially include, but are not limited to, roles such as leader and follower, or independent versus collaborative participation. However, following prior work in social psychology (as summarized for instance in Thibaut & Kelly [27]), larger groups are expected to demonstrate stronger differentiation in roles such as leader versus follower. At the level of the dyad, therefore, I expected to see more collaborative social interaction between the members, wherein both people contribute to wayfinding, though to varying degrees. The question of how this then compares to groups larger than the dyad is still open for further study.

Additionally, I describe navigational performance by different dyads to explain how social interactive strategies contribute to success or failure in solving wayfinding problems, and to identify the occurrence of instances in which participants express indecision and uncertainty during wayfinding. I further investigate how this relates to navigational planning and execution by dyads within which the members already hold a prior social relationship with one another, measured here as pairs of friends who have known one another for at least a year. Then, a follow-up study compares the dyadic performance on the planning and navigation task with individuals' performance on the same task. Overall, this body of work makes a number of novel contributions to our knowledge of context-relevant, collaborative planning and situated navigation by pairs of people working together.

1.3 Structure of the Dissertation

This dissertation is structured around three studies conducted as part of my Ph.D. work, each one building upon the prior to make a novel contribution to our understanding of social wayfinding. In Chapter 2, I conduct a review of relevant background research, discussing the contributions of research in spatial cognition and human navigation. I summarize what we know thus far – and what I propose we should further investigate – about the role that social interaction plays in navigation. I also review the theoretical basis for my approach to the analysis of social interaction in these studies.

Chapter 3 summarizes my first study in this project, which investigates how 30 dyads, previously unfamiliar with one another, plan and execute a route through a novel environment. I present the study methodology, results, and specific discussion of this study. The environment used as the study site is a residential neighborhood with which participants were previously unfamiliar. The central task involves stranger dyads working together to plan a route through the environment from a specified origin and destination point using a paper map, and then physically walking a route between those same origin and destination points in the environment without the use of the paper map, relying only on each other and what they remember to complete the navigation.

In Chapter 4, I describe my second study, which assesses how a different set of 30 dyads, who hold previously-established relationships, perform on the same task of planning and executing a route through a novel environment using only a paper map for planning. In doing so, I study the role of social familiarity in the navigational context. For the purposes of this study, dyads were considered to have a prior social relationship (to be friend dyads) if they had known one another for at least a year and mutually rated each other either "friends," "best friends," or "romantic partners," as opposed to only "acquaintances," "classmates," or "those who spent occasional time together." I compare results of their planning and navigation performance to the results of the stranger dyads in the first study.

Chapter 5 employs a Conversation Analytic (CA) approach to examine several aspects of social interaction that are of particular interest to the domain of navigation and the field of spatial cognition. First, I delineate the basic planning process that the dyads undertake in the context of the two studies, looking at how members of the dyads perform the collaborative process of deciding upon and planning out a route for future navigation. Then, I bring this CA approach into the navigation phase of the two previous studies to examine how leadership is established during initial planning and carried out to varying extents in the real-world navigation task. Finally, I explore how uncertainty is expressed by dyads in communication during both planning and navigation phases of these studies.

Chapter 6 is a follow-up study that addresses the differences between paired and individual wayfinding. In this chapter, I make a comparison with the previous two studies by having 30 individuals perform the same planning and navigation task as the dyads. By interviewing participants immediately following both the planning and navigation phases, I am able to draw initial comparisons between solo and paired decision-making and plan execution. This holds promise for examining the intricacies of individual and group spatial cognition, such as in comparing the differences in information needs between individuals and groups, or whether uncertainty is reduced or heightened when groups work together to navigate through a new environment.

In Chapter 7, the General Discussion, I talk about overall findings and discuss the limitations of my conclusions. I map out future pathways of research that naturally follow from the research agenda set forth here. This dissertation research makes a novel contribution to understanding how wayfinding occurs amongst multiple people working concurrently in a real-world environment. I examine both dyads who are previously unfamiliar with one another and those dyads already in established social relationships with one another, as well as solo wayfinders. I strike a balance between the importance of ecological validity in my findings (by using a wayfinding scenario set in a physical, real-world setting) with the experimental control afforded by the empirical task, kept as uniform as possible across the three studies.

Chapter 2

Background

2.1 Spatial Representations in Wayfinding

Thanks to a robust body of research in the field of spatial cognition, there is much we already know about wayfinding processes for the individual working alone. The starting point for understanding wayfinding behavior lies in the spatial representation of the environmental space. I use the framework by Montello [28] for defining the scale of space in question. *Environmental space* thus refers to the scale of physical space that is larger than and surrounds the body of the person and requires integration of information over "significant periods of time" (p. 315), as it is larger than a *vista space* which can be apprehended visually all at once or from a single location. Forming a spatial representation of an environmental space can involve both the integration of direct experience of the space over time through locomotion, and the use of symbolic representations like maps depicting the space.

In my project, because participants are exposed to a symbolic representation of the relevant study area before acquiring direct experience in the environment, the map representation is expected to influence the structure of their spatial representation of that same environment. This also presents the challenge that participants' individual spatial representations formed while planning may not match what they expect to experience directly (for many reasons, aspects such as scale may be internally mis-represented or mis-remembered), and may influence their navigational performance. But it has been previously shown that prospective planning is not a perfect predictor of one's situated navigation, for many reasons.

2.1.1 The Structure of Spatial Representations

Many scholars have asked the question of how human spatial representations are structured in the mind. If people are able to remember aspects of their environment for the essential act of finding their way around, they must hold a fairly stable and structured representation. The spatial representations that people form, develop, and use over time has been studied extensively in the spatial cognition literature. As early as 1908, Gulliver reviewed historical maps and noted that different cartographic orientations influenced peoples' understanding of the world [5]. In 1913, Trowbridge investigated human spatial orientation and may have been the first to present the idea of an "imaginary map" (mental or cognitive map) of their environments that people hold in their minds and use to orient themselves [6]. The "cognitive map" of Tolman [29] was the most widely-adopted terminology for this kind of environmental mental representation. Tolman interpreted the ability of his rats to take novel shortcuts through a maze as a suggestion that the animals held a cognitive representation of the environment. As Golledge [30] notes, however, further animal research shows the possibility of *dead reckoning* (path integration) as an alternative explanation for this shortcutting behavior.

However, work since has noted many ways in which the idea of a "cognitive map" may not be as map-like as we often assume. Most of this work into spatial representations has been conducted in the field of psychology. Tversky [31] traces the development of spatial cognition in the fields of geography and architecture versus in psychology, and notes that the investigation into cognitive maps of humans was held back "by two related preconceptions": a bias to think of memory and thought as based in language, and the psychological approach of behaviorism, because of the belief that thought and internal mental representations could not be observed (only external behavior).

First of all, metric information is not always present, and even if it is, it is usually imperfect. People have distortions in their spatial representations and are fallible to systematic biases, such as alignment effects or distance distortions [32]. This is due to cognitive organizing principles which simplify – but also distort – remembered spaces. This line of research, with much work ramping up in the 1980s and 90s has taught us that the mental representation of space is no trivial task. It involves not only lower-level mental processes such as the perception and sensing of visual and proprioceptive input, but also higher-level cognitive abilities to allow for the formation and use of such internal spatial representations.

Contrary to a model of cognitive maps as "random degradations of real ones," distortions in peoples' cognitive maps are fairly systematic. The mind reorganizes spatial information through hierarchical organization or categorization, use of perspective, and use of landmarks or cognitive reference points. For instance, in terms of hierarchical organization, one's knowledge of the immediate neighborhood will be predominant over higher-level categories and cause distortions of size and distance, though it is not likely that these distortions are consistent within a person's cognitive map (or cognitive maps). For developing a mental representation of spatial information, the cognitive processes involved all necessarily introduce distortions, and are not surprising given our human facility for distorting other types of information. Tversky [32] gives the example of social stimuli to illustrate these perceptual distortions in a social context. However, it is unclear whether these distortions are introduced into the mental representations themselves or during the processing performed on such representations.

2.1.2 The Acquisition and Use of Spatial Representations

The acquisition and use of internal spatial representations is a regularly studied question in the spatial cognition literature. Spatial representations are formed both through direct experience in the environment and through spatial communication [31]. Direct experience is the acquisition and integration of spatial knowledge through sensory modalities while travelling through the environment, such as through a verbal description of a place. Spatial communication can include use of maps or description to learn about an environment. Both direct experience and spatial communication can be used in conjunction as well, and often is. Many people exploring a new environment while traveling, for instance, first refer to a map to plan out a route or get a "lay of the land." Thorndyke and Hayes-Roth [33] compared spatial learning through direct exploration to learning through map use and found that exploration facilitated pairwise direction estimates, while map use facilitated distance estimates. In my research, I look at both sources of spatial knowledge acquisition, with people using a paper map for first exposure to a new environment, followed by direct experience in that environment. In this project, I do not directly measure what participants learn about the environment itself; however, I indirectly assess participants' spatial learning through their application of that spatial knowledge established with their wayfinding partners to jointly complete a navigation task. This includes the ways in which the navigators in the real-world environment are able to recognize cues, anticipate and coordinate upcoming actions, and adapt their planning *en route* to unexpected challenges.

This is relevant in terms of how people learn and develop these representations of their environment over time. Spatial representations are not formed "all at once" with exposure to a new environment but are formed with additional experience, both direct and indirect. Researchers have generally settled on an approximation of three main types of spatial knowledge representation: landmark, route, and survey knowledge. The framework by Siegel and White [34], which presents a progression between discrete stages of development, has been considered the "dominant" framework [35], in contrast with the "alternative" framework of continuous spatial microgenesis presented by Montello in 1998 [36]. Siegel and White first proposed in 1975 that spatial knowledge acquisition followed a progression through qualitatively different levels of spatial knowledge, such as the landmark, route, and survey representations described above [34]. This framework states that each stage follows the previous in a cumulative fashion, and is called the "dominant" framework because of its widespread acceptance and use in the field of spatial cognition. Siegel and White recognize that these internal maps are rarely complete, and many scholars since have explored systematic distortions in peoples' cognitive maps. They also claim that the microgenesis of spatial knowledge mirrors the ontogenetic development of spatial knowledge from infancy and childhood to adulthood.

Ishikawa and Montello [37] further describe the process of spatial cognitive microgenesis (the development of *spatial knowledge acquisition*) with twenty-four students previously unacquainted with two different routes in a neighborhood called Hope Ranch. The authors challenge the idea that knowledge development follows the linear progression from landmark to route to survey knowledge as proposed by the dominant framework of Siegel and White in 1975. However, this learning must have some relevant order of development (i.e. more metrically-complete survey type representations are not likely to exist *before* route or landmark knowledge). Because of the way people experience movement, it may be counter-productive to assume we could develop landmark knowledge without route or survey knowledge to link these landmarks together, or at least place them in context. This is shown in the performance of the participants, who had already acquired some route knowledge after the first session. In the presented results, landmark, route, and survey tasks all seem to relate to a shared cognitive representation. Therefore, in the microgenetic sense of learning a novel environment over a shorter period of time than the lifespan, route and landmark learning can occur rather than in succession. For instance, landmarks serve as anchor points for the organization of regions and other spatial knowledge [30].

People additionally differ in their preferences or strategies for remembering routes and navigating through the environment [38]. As with self-reported general sense of direction measures, I expect that people have some level of access to their internal strategies for remembering, and be able to partially describe those strategies. However, it is unclear how much is accessible to the person performing the task. Social communication between wayfinding partners during planning and navigation will help us draw out these practices.

In planning a route ahead of time or carrying out a route plan in a situated context, people employ a number of relevant spatial abilities. Allen's framework [39] considers functional behavioral applications of spatial cognitive abilities, and suggests grouping these abilities by reference to what behaviors they enable. For instance, cognitive mapping relates to the comprehension of geometric spatial relations between observed places as well as inferences about unobserved places (pp. 70–74). Following from this discussion by Allen on the types of wayfinding 'means' employed to perform specific wayfinding tasks (familiar travel, exploratory travel, and travel to novel destinations), navigating between destinations in a novel environment is likely to relate to piloting between landmarks, using path integration, or wayfinding by reference to a cognitive map.

2.2 Wayfinding Research Methods

For my research, I am interested in how these mental representations are recalled, communicated, and re-worked in paired wayfinding: how people verbalize or otherwise communicate their existing mental representations of a large-scale environment for the purpose of wayfinding, and how these individual representations may be shared and revised together to orient to a specific wayfinding task. I expect there will be differences between individuals in their internal spatial representations; how, then, can we understand the underlying spatial representations applied to the task? How do individuals come to understand the extent of their shared representations and reconcile the differences in their mental models of the environment? Important methods employed in my set of studies to elicit these mental representations include the use of sketch maps (as route sketches), verbal description and communication, and navigational performance [3].

2.2.1 Navigation in Real-World Environments

Studies that use measures of navigation in the real world context do so primarily by assessing performance through measures of time or distance, amount of deviation from shortest route, number or stops or pauses versus time spent moving toward goal, landmarks identified or used, and so forth. These measures have the most ecological validity because they are conducted in an environment that more closely resembles the spaces in which navigation is actually performed by people in their day-to-day lives. To study wayfinding in complex buildings, for instance, it seems logical to have people find their way in a building rather than in a virtual reality rendition of that building. But real environments are often noisy – there are many unaccounted for factors that may cloud the researcher's ability to detect the real effects present. Additionally, most real environments are specific, in that they exist in a particular way and have a particular history and meaning to people, and results may be less generalizable to other environments if this is ignored.

The navigation of expert practitioners has also been explored to understand the effects of extended navigational training for highly spatial professions or recreational activities. The most prominent set of studies in this realm is the work of the London taxi drivers [40, 41]. The researchers review the role of expertise in spatial navigation and the corresponding influence on the brain. London taxi drivers have to undergo rigorous training and testing on their map-like representations of the city over the course of several years while studying for the intensive exam called 'The Knowledge'. Using age- and experience-matched subjects who were either London taxi drivers, who had undergone (and passed) The Knowledge, or London bus drivers, who only drove a fixed number of routes during their work, they found important differences in hippocampal grey matter volume in the right posterior and anterior areas based on years of navigation experience only for the taxi drivers; this difference was not observed in the bus drivers. They also used various cognitive measures to determine whether performance differed between the groups, and found that the taxi drivers were better on the London landmarks recognition and proximity judgments, but poorer on the visual recall task. Studying the development and strategies of experts in acquiring and using such extensive spatial knowledge may provide additional avenues into the study of real-world navigation.

2.2.2 Navigation in Virtual and Augmented Reality

Virtual reality (VR) environments are a newer avenue for conducting spatial navigation research, and there has been strong uptake by researchers to use VR environments for spatial cognition research, at both small and large scales [42]. The advantages to using measures of navigation in VR environments are numerous. For one, the environment can be controlled in ways that are not possible in real world environments. Modelling an environment in VR, for instance, can provide a setting that is consistent across all participants, whereas an environment such as a streetscape would naturally vary in ways that may affect data collection: people may be present in different numbers or in different places, lighting and shadow may impact participants' ability to orient themselves, different landmarks may be available, and so on. It is also relatively easy to set up various conditions in ways that would be impossible in real environments, such as systematically varying a single aspect of the environment while holding all else constant.

The challenges of VR navigation are numerous as well [42]. One obvious disadvantage is the time and expertise required to program such environments. Whereas a real-world navigation study can select an existing environment, virtual environments must either be created from scratch or repurposed from another source (though even in that case some additional programming would likely be required). VR environments vary in their *perceptual fidelity*, the dimension of VR 'realism' experienced by users. New technological advances are resulting in more realistic, immersive environments with lower barriers to programming and design, making virtual reality more accessible to future research. Overall, it appears that VR holds much potential for spatial cognition research, and that research in this realm has been accumulating quickly. However, it will always be important to compare behavior in virtual environments with that of real-world behavior.

2.3 Wayfinding Communication

People regularly need to communicate spatial information with each other in their daily lives: to help others find their way from place to place, describe where things are, and make plans with one another. Despite a growing reliance on the ever-present digital navigational aids built into our cell phones and accessible from almost any location on earth, people flexibly apply their spatial knowledge to the everyday tasks and situations they are confronted with. As long as humans are still engaged in the act of wayfinding, the design of any navigational device will continue to rely on research into how people understand place descriptions, route directions, and visual displays.

Successful route planning and navigation depend on related skills and strategies as well as some separate considerations. Planning a route depends on a representation of the environment (whether internal or external) with which to work. It involves considering the available options for movement, such as the network of roads or sidewalks, and knowing the criteria with which to make decisions about the plan, such as minimizing distance to the destination or increasing one's enjoyment or safety along the route. In this section, I discuss prior work on route direction-giving, which helps us understand the structure and necessary elements of a complete route description.

Navigation along a route, on the other hand, presents additional situated challenges of remembering the route plan, understanding the correspondence of the planned route to the experienced physical environment, maintaining one's orientation, judging distances, and often coordinating one's spatial knowledge with others. I consider here what it means for a person or persons to "be lost" and strategies people use to re-orient themselves when that happens. I also argue for the importance of using real-world settings for the purposes of studying navigation as people actually experience it.

2.3.1 Route Directions

Spatial cognition broadly deals with questions of how people acquire, use, and communicate spatial knowledge, and has always been interested in the nature of spatial language. One way in which people communicate spatial information is through the use of route directions: a sequentially-structured set of instructions used to identify a route from an origin to a destination. Investigations into route direction-giving allow us to better define the structure of a complete set of route instructions and what is at the core of a route plan.

Psathas and Kozloff [43] outlined typical elements present in the structure of directions as parts of three main phases: defining the situation, information and instruction, and ending phases. The protocol in their study consisted of informally recorded telephone conversations where the authors asked people to give directions to certain places. The insights into the basic structure of preparing route directions for another person are useful to examine, and helps identify features considered essential or typical to direction-giving. In the first phase of defining the situation, the director (the one giving instructions) must have an idea of the starting point, end goal, means of transportation, and the recipient's familiarity with the environment. Some of these may not be provided explicitly in conversation, but may implicitly be provided, allowing one or more of these elements to be assumed by the director. In the information and instruction phase, the director provides route information based on paths, directional reference points, and orientational reference points. In this way, the receiver knows what he or she is searching for to make a change of direction or to gain reassurance that the travel direction is correct.

Later work by Psathas [25] emphasized the sequential organization of spoken route directions, in which one operation is assumed to follow another on the route when it follows another in a conversational turn-at-talk. In this way, a route description mirrors the sequential nature of traveling along a route. However, direction-givers do not have to necessarily start at the origin point – they may make a 'jump move' in conversation to a secondary known place to use as an alternative starting point. Wunderlich and Reinelt [9] proposed a similar structure of direction-giving, identifying four phases: phases of initiation, route-description, securing, and closure. The authors also posed that the task of communicating route directions is split into the cognitive, interactional, and linguistic subtasks. This delineation of subtasks emphasizes that even a task such as direction-giving cannot be reduced to a simple information transfer between two people. Instead, giving route directions requires attention to all three subtasks in tandem: the task depends on both parties involved to communicate about the necessary information, each to cognitively process the information in relation to one's cognitive map, and the informant to describe the route linguistically.

Though these studies mentioned outline the basic structure of route directions, they do not attempt to empirically determine how often people employ different types of references in giving directions or what constitutes effective route directions for the receiver. Further work in the areas of spatial cognition – including geography, psychology, linguistics, artificial intelligence, and possibly others – has to date identified a number of general characteristics of good versus poor route directions. Referring to the stages of route communication identified by Wunderlich and Reinelt [9], Allen [10] tested a number of principle-based 'best practices' for giving route instructions identified by psycholinguistics and discourse processing. The results of his experiments lent moderate support to these principle-based ideas for what make some directions better than others. Allen found that uncertainty was reduced through use of descriptive statements rather than directive statements at choice points on the route, which directs attention to a critical part of the route by relaying a visual description of it, and that the advantages of having descriptives associated with choice points may be greater for latter portions of the route, supposedly where memory demands are highest. Also, he found that delimiters (distance and direction designations, including units, reference frames, relational terms) used at choice points improved route executions and reduced information failures. This study additionally noted important sex differences in the ability of men and women to follow the given route directions.

2.3.2 Key Features of Route Descriptions

To tackle this problem from another angle, Denis and colleagues have established a novel method of generating “skeletal” (bare-bones) route descriptions in a standard format that they have empirically tested in several studies. In one set of studies in the city of Venice [11], the researchers first collected descriptions of three routes and analyzed the lengths of each description as well as the landmark references to find that landmarks serve different functions at different parts of the route. Reduced “skeletal” versions of each of the three routes were then generated from the core information units commonly identified as relevant by most participants. A different set of participants, half of which knew the city well, then assessed the originally collected route descriptions. Judges in this study who were familiar with Venice commented on the features they believed made ‘good’ route descriptions: clarity and completeness, a sufficient number of landmarks, and a lack of redundancy or indeterminate directions. There was a significant correlation between scoring of the familiar and unfamiliar judges, though greater consistency was observed in the scoring by the judges who knew the city well. The authors conclude from this that the judges must have used similar criteria to rate ‘good’ route directions.

Landmarks are especially important to include in route instructions. They are more useful to conveying spatial information than street names and may have a lower cognitive processing cost [44]. Though landmarks themselves do not provide information about actions that need to be taken as part of the route, they make reference to the visual environment available to the direction-receiver. Good route directions do not necessarily contain more landmark descriptions, but they concentrate these mentions of landmarks more closely in speech to mentions of actions. Allen [10] found that people do tend to behave based on principle-based best practices for communicating route knowledge, one of which is to concentrate this relevant action information to choice points along the route. However, it is worth noting that these studies of route instructions focus primarily on route-based representations. It is important to examine perspective-taking in relation to landmark use, as encountering the same landmark from different directions will cause problems in orientation and wayfinding if one has only remembered the cue and the egocentric turning direction associated with it.

Communicating a route to another person requires establishing common ground between two or more people's individual spatial representations [10]. Following the previous work of Clarke and colleagues, Allen describes this ability of people to establish and maintain common ground with one's partner. Allen also showed that people are receptive to mutual knowledge and show an orientation to one's partner – what they know, but perhaps also their spatial abilities or preferred navigational styles. Recent work by He, Ishikawa, and Takemiya [18] show support for the flexible adaption of route instructions to one's partner based on spatial ability, so it seems that people are aware and conscious of this when providing route instructions.

Hölscher, Tenbrink, and Wiener [14] investigated whether people employ different strategies in wayfinding tasks based on situated or prospective planning. They predicted that situated navigation would influence people to rely primarily on a direction-based strategy wherein they could change their plan while navigating, whereas in prospective planning the participants would plan to take more main roads (which would be more salient and cognitively accessible to them). Additionally, if routes are always planned in advance rather than revised en-route, there should be no systematic difference apparent in route choice between the conditions. The authors compared the two conditions as well as a condition in which participants were prospectively planning for a person other than themselves.

They found that in situated planning, where participants navigated through the environment and could revise their plan on the go, people would take a different route for themselves than the one they provided to another person, using routes that included a significantly higher number of streets and turns. This is based in differences shown between what was thought to be important for constructing good routes for oneself and for others: Elements of effective routes planned for other people were identified as simple, with few direction changes, and containing distinctive and helpful landmarks. Elements of effective routes planned for oneself (in both situated and prospective conditions) were identified as attractive, not too busy, fast, short, and direct. This presents convincing evidence that people use more incremental planning strategies in situated navigation than do when planning in advance. Additionally, route plans intended for others included more detailed descriptions (were of higher "information quantity," as the authors describe it), used to establish more common ground between the planner and the addressee.

The results of these studies suggest that recorded plans of intended behavior are significantly different from navigation in the real-world, supporting an argument for more *in situ* field studies of human navigation. This verbalization by participants about routes and the processes they use in wayfinding is a productive approach to collecting data about their spatial representations. Further work should additionally look at verbalized data in other aspects of spatial communication, such as during real-time navigation in conjunction with a partner.

However, for all we know about what constitutes good route directions, there is still much we do not know. For instance, we observe from studies such as that by Wunderlich and Reinelt [9] that people use implicit cues such as current location and elements of speech such as pauses to infer information about where the speaker is, what he or she knows, and how much uncertainty he or she has. What other cues may signal to the speaker the type or completeness of directions to give, such as based in the receiver's spatial expertise or familiarity? How might a person's gender or perceived social role enter into this determination? Put another way, how do we account for this unspoken information that contributes to the formation and application of good route directions?

2.3.3 Getting Lost and Use of Navigational Aids

Spatial disorientation and misorientation are common problems threatening any navigation activity. Both spatial disorientation and spatial misorientation are problems of orientation, either with regards to which way to go or with regard to where one is in relation to the remembered map or route. When one is spatially misoriented, you are objectively not where you think you are, or not going the correct way towards the goal destination. However, one can be misoriented and not be conscious of it. Spatial disorientation refers to cases in which one additionally recognizes that one is misoriented – you are aware that you are not in the right place or unsure about where to go [15]. The issues facing accurate spatial orientation are numerous, and include spatial problems of self-localization, recognition of landmarks or other features, memory or robustness of one's spatial representation, and the correspondence between one's representation and the actual environment. Other issues include social factors such as disagreement between navigational partners, or physical factors like low visibility, poor signage, and so on.

Problems with orientation are obstacles to successful navigation, and people have many available strategies to overcome these obstacles. From the search-and-rescue practitioner's experience, Hill [16] outlines the strategies used by lost people to attempt to reorient themselves. As outlined by Hill, these comprise: (1) random traveling, (2) direction traveling in a specific direction, (3) route sampling from a given intersection, (4) direction sampling for short distances in various directions away from a landmark or base location, (5) view enhancement through getting to higher ground or a place with greater visibility, (5) backtracking one's previous route, (6) using folk wisdom, and (7) staying put and waiting for searchers. The discussion of these strategies will help inform my characterization of the navigation-relevant behaviors employed by participants in my studies, as all of the above were used to varying extents.

One may ask whether the problems of spatial misorientation can be avoided through the use of digital navigation assistance systems (such as in-car GPS navigation systems), in which self-localization information and turn-by-turn instructions can be provided. This may be the case in many situations where such a system is available, but long term over-reliance on such systems has been shown to result in degradation of one's spatial abilities [45]. 'Offloading' such spatial skills to external systems on a regular basis can lead to dangerous situations. The over-reliance on such systems could put one in potential danger in situations where the systems fail, are misused, or become unavailable. Examples of such incidents are well documented in the popular press, and can certainly be dangerous or fatal in extreme cases. Researchers are attempting to combat some of the effects of these systems by designing more cognitively-informed navigational aids, including cartographic maps as well as these digital navigation systems. For instance, Gramann et al. [46] have assessed human processing and encoding of spatial information with navigation instructions that included landmarks and found that modified navigational assistance led to long-lasting incidental spatial learning.

2.4 Personality, Gender, and Individual Differences

People exhibit large differences in their individual ability to navigate through an environment, from those who are very good at finding their way to those who may be no better than chance. Though some of this performance can be attributed to aggregate group differences such as gender or culture, there is also evidence of much variability in navigation performance amongst individuals. Research on individual differences is important for several key reasons outlined by Hegarty and Waller [47]. Measuring individual differences helps us account for variance among people; we know from previous research that spatial abilities demonstrate wide and pervasive individual differences; and individual differences may be wide enough that they cloud other variables, by making them harder to detect [47].

The wide difference in peoples' spatial abilities can be summarized along three dimensions important to this research agenda: individual differences in spatial cognition, personality, and gender. Prior experience with the specific environment in question is controlled for in this study, as participants had no familiarity with the study area. However, in many real-world navigation contexts, we cannot typically ignore environmental familiarity as a contributor to successful wayfinding.

2.4.1 Individual Differences in Sense of Direction

In terms of measures for studying spatial abilities, researchers have often relied on pen-and-paper psychometric tests to assess "small scale" spatial abilities [47, 48]. These are sometimes applied as an imperfect and limited proxy for spatial abilities at scales beyond that of the tabletop as well. However, "large scale" spatial abilities – in environmental space, which is too large to be apprehended from a single place without locomotion [28] – differ from these small scale spatial abilities. Large scale spatial abilities contribute to the acquisition of spatial information over time, integrated into the representations that people hold of their environment. Notable differences between large and small scale spatial abilities inspired new measures to gather data on sense of direction through self-report, in which people rate on a scale their own ability on perform certain tasks. Most relevant to real-world navigational ability is *sense of direction* (SOD), the ability to locate and orient oneself with respect to an environmental space. The most notable self-report measure of environmental spatial ability is the Santa Barbara Sense of Direction

(SBSOD) scale [49]. The SBSOD is a generalized self-report measure of navigation ability, commonly used in spatial cognition research and not specific to Santa Barbara (despite the name).

It is clear not only that people have a good sense of their own navigation ability but that their self-report of the dimensions of this ability is also reasonably reliable. The advantage to this type of self-report measure is that it is more efficient than testing performance on a navigation task in a real environment and has been shown to correlate with performance on spatial learning measures in real environments [48]. It has much lower costs in terms of administration time and monetary expense than other measures, as self-reports usually consist of a short, paper-based or digitized set of questions. A notable disadvantage of self-report is that it is an indirect measure. It requires people to access their mental states, such as their beliefs about their own ability to navigate, which means it is subject to a number of cognitive biases [3]. It is also prone to the effects of other factors, such as personality or gender. For instance, some people may be more confident in their abilities even if actual performance is on par with others. Or women may exhibit more anxiety in spatial performance or doubt their own ability because of stereotype effects [50].

Ishikawa and Montello [37] demonstrated that peoples' ability to acquire and integrate spatial knowledge over time through direct experience varied widely between individuals. In their study, the researchers drove participants individually through the study area over the course of 10 weeks. Individual analyses of participants' sketch map drawings and their direction and distance estimations over the 10 weekly sessions showed that some participants maintained highly accurate spatial knowledge starting from the first session, while others showed significant improvement over time, and some never improved from their low performance across sessions. This supports the idea that people differ in how they form spatial representations, with some acquiring accurate metric survey information quickly and others failing to do so even after multiple hours of direct experience.

Navigational performance based on different spatial strategies may also depend upon the format of the provided information, such as shown with map versus verbal instruction in the study by Pazzaglia and Rossana De Beni [51]. It seems that the effect of type of instruction was more influential in individuals' performance than their grouping by scores as landmark- or route-centered, meaning wayfinding performance could be improved across all individuals by making these kinds of changes. However, this does not discount the importance of individual differences in learning how people might choose one strategy over another (or combine strategies) in real world navigation.

Hegarty, Montello, Richardson, et al. [48] present hypothetical sources of individual differences in large-scale spatial cognition, including that of memory, or the ability to maintain a 'quality' representation of spatial information obtained from sensory experience. The review by Wolbers and Hegarty [52] evaluate explanations in the literature for differences in navigation abilities and name a number of findings from behavioral studies that point to individual differences in perceptual and cognitive processing. Hegarty and Waller [47] note that the large differences apparent in individual spatial abilities may pose a threat to detecting the effects of other variables in an experimental design. To account for this, a study of a variable's effect on spatial ability could be improved by using additional differential methods together with experimental methods. This would help tease out whether effects of the manipulated condition would differ based on the individual's spatial abilities. Attention to experimental design is an essential consideration for the explanatory power of any similar study.

2.4.2 Differences in Personality

The way in which individuals vary in their behavior in fairly consistent ways across different scenarios and across time is commonly referred to as their personality. Personality factors such as extraversion or compliance have mostly been excluded in wayfinding studies, though perhaps for good reason – aspects of personality may play a larger role in interpersonal, rather than individual, decision-making, and in general the majority of wayfinding and navigation studies have focused on the individual. In general, individual differences in spatial ability have been more adequately addressed in the existing literature, as described above. However, a number of researchers have attempted to delineate the relationship between personality factors (such as extraversion and openness to new experience) and sense of direction.

In 1982, Bryant [53] used a sense of direction questionnaire and a psychological inventory (among other measures) to look at the influence of personality traits on sense of direction and geographical orientation. Students completed a self-report sense of direction (SOD) questionnaire, the California Psychological Inventory by Gough [54], and the Vandenberg and Kuse [55] mental rotation task, and were then tested on their directional estimates to various places on campus using a pointing task. Bryant found positive correlations between self-reported SOD and personality attributes. The findings suggest that personality relates to pointing performance, but is mediated by aspects of liking to explore, spatial anxiety or worry about becoming lost, and familiarity with routes. Even accounting for these mediating variables, the personality scores for the traits labeled *Capacity for Status*, *Sociability*, and *Self-Acceptance* significantly related to pointing performance. Personality may relate to geographical orientation in that "variations in interpersonal style may result in individuals' engaging the spatial environment differentially, resulting in differential accuracy of mental representations" (p. 1323).

Personality is especially important to this research project because it influences how people interact socially, such as in establishing leadership within groups. Whenever two or more people interact, there is the possibility of someone taking more of a leadership role, and this is thought to be influenced by personality factors. Using a common measure of major personality factors called the Big Five Inventory, Judge et al. [56] showed that *Extraversion* has been most consistently shown to correlate with leadership, followed by *Conscientiousness* and *Openness to Experience*. Personality factors have also been shown to specifically relate to sense of direction, which is an important measure of environmental survey abilities in spatial cognition. Condon et al. [57] related sense of direction to the Big Five personality characteristics and showed that the four of the Big Five personality traits – *Conscientiousness*, *Extraversion*, Intellect (or *Openness to Experience*), and Emotional Stability (low *Neuroticism*) – related to sense of direction results. The correlations for those four traits ranged from .22 to .32, which is reported by the authors as low to moderate. However, we should expect personality to have greater relevance with regards to social wayfinding behavior, by dyads working together.

The personality inventory used in my dissertation is called the five-factor model of personality [58, 59]. This is referred to as the "Big Five" structure of personality, consisting of the five main factors of *Extraversion*, *Agreeableness*, *Conscientiousness*, *Neuroticism*, and *Openness to Experience*.[1] The Big Five is well validated by many separate factor analyses and meta-analyses and ties in closely with previously proposed personality trait inventories (see John et al. [60, p. 115]). Each main factor dimension also corresponds with a number of facets and verbal labels. Extraversion typically relates to sociability, describing individuals who may be thought of as outgoing, active, and dominant, and includes facets such as enthusiasm and positive emotionality. Agreeableness

[1] The Big Five is also sometimes referred to as the "Big Five Inventory" (BFI), or abbreviated as "OCEAN" for the first initial of each of the factor names [60].

refers to a communal, altruistic, or prosocial orientation towards interpersonal behavior. Conscientiousness describes impulse control with regards to social norms and rules, and relates to persistence, planning, organization, and self-control. Neuroticism is generally described as a negative emotionality, relating to traits of anxiety, worry, and nervousness. Openness to experience is the most controversial of the five, but is generally meant to capture originality and open-mindedness with regards to learning and new experiences. The NEO-PI-R assessment by Costa and McCrae [61] includes 240 items, but the shorter version presented by John, Naumann, & Soto [60] is used here in my studies. This version includes 44 items, significantly reducing administration time while preserving many aspects of the full assessment.

2.4.3 Gender Differences in Wayfinding

Differences in wayfinding and other spatial abilities have been shown to relate to gender as well. Lawton [50] summarizes important aspects of gender to wayfinding abilities and behavior, including the role of environmental exploration behavior and potential differences due to gender, as well as the gendered development of spatial anxiety. It does appear that gender differences in spatial anxiety account for some of the difference in spatial exploration behavior between males and females as well, for the purposes of harm avoidance in women [62, 63]. Other explanations of gender differences in spatial behavior have to do with differences in mobility, where men tend to travel longer distances than women in many cultures. Voyer, Voyer, and Bryden [64] (1995) conducted a meta-analysis of sex differences in spatial cognition and explored the possibility that changing social factors played a role in reducing the effect of sex differences over time (as claimed by Feingold, 1988). However, as the authors recognize, these influences are difficult to isolate from all other potential factors - environmental, biological, and so on.

Two studies strongly suggest that gender differences in exploration behavior relate to route selection, navigational efficiency, and spatial memory [65, 66]. In Boone et al. [65], the differences between male and female route selection and navigation behavior related to efficiency measures in a virtual maze environment (modelled on the Dual Solution Paradigm by Marchette et al. [67]). Males more often shortcutted using novel routes, while females more often followed learned routes and wandered. Within a large-scale novel virtual environment, Gagnon et al. [66] also found that females revisited previously explored locations more often and dispersed less throughout a new environment during initial exploration. These gender differences in exploratory behavior partially accounted for the differences in the spatial memory measures administered in their study. Therefore gender and spatial exploration behavior are an important facet of this research into the strategies for learning of new environments, selection of routes, and navigating to a goal location.

2.5 Social Wayfinding

Studies of cognition in culturally and socially plausible settings are critical to our understanding of human navigation and wayfinding, but are less common due to the difficulty of generalizing lab findings to real-world contexts. Cognitive processes have primarily been studied in isolation from these social contexts, and psychologists, sociologists, geographers, and other researchers in spatial cognition have not yet adequately explored the social dimensions of wayfinding behavior. However, researchers are beginning to directly address navigation as a shared task undertaken by two or more people, shown by the recent influx of enthusiasm around the topic (to name some examples, Haddington [24]; He, Ishikawa, & Takemiya [18]). These and other studies are beginning to form our base of knowledge about the role social interaction plays in human wayfinding and navigation.

However, a majority of the prior work in spatial cognition has taken an individual approach to the study of wayfinding, isolating the planning and decision-making process of a single person as the unit of study. We know for instance how a single person looks at a map and plans a route (see for instance the discussion of map-reading strategies summarized in Lobben [68]), and we know something about choice behaviors at decision points along a route (see work such as Tenbrink & Wiener [69] and Meilinger, Franz, & Bülthoff [70]). But we fall short in understanding how this scales up beyond the individual to the group level. This points to a limitation in our understanding of the wayfinding process as it unfolds in a social context, as it often occurs in real-life navigational scenarios. People often wayfind in conjunction with another person, whether a long term partner or a spontaneous travel companion, or as part of a larger group such as a work team. Limited prior research supports how navigation may work for pairs or groups of people: What strategies contribute to success in these types of interactions? What are some of the unique challenges or behavioral effects facing pairs or groups of people in navigation?

Methodological difficulties arise from the added complexity involved with expanding experimental psychology paradigms beyond the individual level of analysis, such as bi- or multi-directional relationship factors and interaction effects. The recent expansion of virtual reality (VR) studies in human navigation have also re-shaped the research landscape in spatial cognition, with many new studies incorporating VR environments. Virtual reality has the advantage of greater experimental control, in which 'physical' environments are more easily manipulated and controlled to isolate specific factors of interest [42, 71, 41]. Dalton et al. [17] cite the use of VR in wayfinding studies as an additional reason for this focus on the individual as the unit of analysis. Experimental contexts favor studying the individual's actions without the presence of other (modeled) people, and modeling others in a VR environment beyond a highly simplistic and non-interactive manner would again introduce more complexity. For instance, two separately-controlled avatars modeled in a VR world would also have to include as part of the interface a way to communicate with one another, whether that is solely verbal or written speech or that includes virtual gestures and facial expression.

Due to the research gap in group navigation, the social aspects involved in wayfinding have been generally been under-recognized. There have been a few studies that incorporate social aspects of wayfinding, including the construction of route descriptions for others [11, 14]. Although these are spatial descriptions provided in interpersonal situations, even route description and direction-giving are primarily individual activities. Denis et al. [11], for instance, combine multiple individual route descriptions to look at common aspects shared across these provided descriptions of the same route. While this demonstrates that there are objectively important considerations in directing others' wayfinding through an environment, the study does not explore what makes paired navigation performance more or less effective.

Behavioral studies focused on paired navigation have shown that people appear to be attuned to the navigational ability of their partner in terms of how they provide route directions. In a study on simultaneous route direction-giving and -receiving by pairs of participants, He, Ishikawa, and Takemiya [18] found that those pairs of people who were more efficient in their navigation performance mentioned cardinal directions more frequently and overall gave a fewer number of instructions to their partners. But the authors also paired their participants using a sense of direction assessment (high-high SOD, high-low SOD, and low-low SOD pairs), and their qualitative analysis of the conversation between partners pointed to the important consideration of one's partner's ability: participants with a better sense of direction were better able to adjust to the needs of their partner, adjusting their navigation instructions accordingly. They were able to do so both because they stored more and potentially varied information about the environment they had traversed, and they were more attuned to their partner's needs. This demonstrates the need for flexibility in social coordination between members of a dyad, which may help overcome the disadvantages of being a poor individual navigator. Pairs of people, as shown by He et al. [18], perform differently than individuals because of differences not only in their individual sense of direction, but also in their interpersonal route communication.

Hölscher et al. [14] similarly explore route description and navigational performance, but further compare prospectively planned versus situated route execution. In their study, they compare route descriptions that participants prepared for their own prospective navigation to the route they follow in the same situated context, as well as to those they prepared for others. The series of experiments they describe show support for a "profound difference" between situated and prospective planning, wherein participants often modify their route-following *in situ*. Route descriptions planned for others ahead of situated navigation scenarios appear to be more aligned with communicability, and will for instance tend to be longer in description to build up more common ground for a less knowledgeable addressee. Participants showed a tendency to use fewer, larger roads and fewer turns when preparing a route for others to follow than those they used for themselves in a situated navigation scenario. Route planning as it plays out in situated navigation differs in that it is more incremental, akin to what Heft [72] calls "a temporally unfolding interaction between the wayfinder and the affordances of the environment" (as quoted in [14]). This difference between situated and prospective wayfinding will be interesting to explore in more explicitly social ways, as a collaborative task between pairs of people rather than as performed by individuals for themselves or others.

2.5.1 Relevant Aspects of Group and Dyadic Social Interaction

My interest in studying navigation from a social interaction perspective is related to how people share spatial knowledge in a task-oriented setting specific to navigation, how they establish social roles in groups, and how they interact with one another to deal with common wayfinding challenges such as uncertainty at decision points. Navigation research has predominantly taken place at the individual level of analysis, but real-world navigation is a phenomenon that always occurs within social contexts, and often explicitly in conjunction with other people.

Group size is an important consideration in this proposed line of study, as there has been strong support for the idea that the number of people in a group impacts behavior and interaction. A two-person group is qualitatively different from a three-person group, a three-person group different from a four-person group, and so on. Research into group navigation in a non-human context suggests that there is a non-trivial difference between an individual navigating and a group of individuals navigating, beyond a simple 'additive' effect. Simons [73] describes research on bird flocking behavior that aligns with the *many-wrongs principle*; the many-wrongs principle, proposed by Bergman and Donner [74], describes how standard error—such as in directional accuracy—is decreased with increased group size. Simons states: "The elegance of the many wrongs principle lies in its simplicity: the navigational advantage is gained automatically through group cohesion alone" [73, pg. 454]. Observational data shows that greater accuracy in bird navigation is shown with increasing group size.

Correspondingly, work by Hutchins [2] proposes that group cognition may have qualitatively different properties than individual cognition. Hutchins's work on "cognition in the wild" explores shared spatial cognition during ship navigation by a Naval team. He studied the organization of the crew's performance to look at cognition as a socially distributed activity, situated in the real world, rather than as a solitary mental act carried out independently by an individual. It is unlikely that the human group equivalent could be presented in as straightforward a formulation as the many wrongs principle in ecology, but perhaps group navigation principles seen in animal behavior may further inspire our studies of human social navigation.

Dyads, or pairs of individuals working together toward a shared goal, will be used as the unit of analysis. Social geometry is a well-recognized concept stating that with each individual person added to the group, different social behavioral dynamics are introduced. This makes, for instance, the social behavior of triads and larger groupings fundamentally different than that of dyads. Simmel [19] identified important differences between groupings based on membership size, such as noting that a triad has a tendency to self-segregate into a dyad and an isolate (individual). These added complexities make it necessary at this stage to limit this line of inquiry to the simplest size social group. However, this set of studies will help inform further studies of the small group of three or more, and is expected to complement concurrent work by other researchers in team cognition and spatial behavior. Measures based on the individual participants will also be included. This research straddles the line between the methodological traditions of psychology, which conventionally examines the individual, and sociology and geography, which generally apply group-level analyses.

Zajonc [75] described the impact of social facilitation, a long-recognized psychological phenomenon, on group interaction behavior. Zajonc outlined the primary effects of social facilitation on group behavior through the processes of audience effects and co-action effects. Audience effects are those in which dominant responses, such as trained performance on simple tasks, improve in the presence of an audience, while acquisition of new responses is impaired. More significant to this area of research, co-action effects are those in which the presence of others while working on a task similarly facilitates performance and impairs learning.

Clark more specifically addresses the effects of joint action in the context of collaborative behavior [76]. People necessarily establish shared common ground between themselves in their language use. Their personal common ground may be based in perception, action, and social relationships. In order to coordinate with one another, people make use of both linguistic and material signals to coordinate their actions [77]. In their review of psychological research on joint action, Knoblich, Butterfill, and Sebanz [78] distinguish between planned and emergent coordination of behavior, both of which are examined in this research. In general, planned coordination "requires a plan that specifies the joint action outcome, one's own part in a joint action, and some awareness that the outcome can only be brought about with the support of another agent or force" [78, p. 65]. Emergent coordination, on the other hand, describes how behavior "occurs due to perception–action couplings that make multiple individuals act in similar ways, independently of joint plans" [78, p. 59]. All of these recognized practices are dependent upon both physical and social contexts in order to organize action and common knowledge.

2.5.2 The Dimensions of Social Wayfinding

Dalton et al. [17] propose a framework for social wayfinding which distinguishes between strong versus weak social wayfinding, as well as between synchronous versus asynchronous social wayfinding. Both strong and weak social wayfinding contribute to how people take cues from others to help find their way through an environment. In strong social wayfinding, people work directly with others to find their way to a goal location. There is a higher level of intentionality between the actors and they interact directly with one another. This is contrasted with "weak" social wayfinding in which people may be interacting indirectly or implicitly, such as through following the general movement of a crowd or traversing a well-trodden path through the woods. The synchronous versus asynchronous dimension of social wayfinding depends on the co-presence of the actors in time and space and thereby shared perceptual access. Synchronous social wayfinding is that which is done in conjunction with another person at the time of navigation, rather than for instance having one person provide route directions to another ahead of time. The actors are temporally and spatially present together, whether or not they are directly interacting towards a shared goal.

My studies contribute to the budding research around social wayfinding, particularly in regards to strong social wayfinding. It will be illuminating to see how dyads plan and execute routes in novel environments of different kinds, either with a known or unknown partner. Additionally, I expand on the social dimension of strategy differences used in situated versus prospective planning, as explored on an individual basis by Hölscher et al. [14]. This research contributes to the understanding of how people align pre-existing spatial knowledge with others in order to solve the important problem of navigating through the physical environment. People working in groups take on specific roles, such as leader and follower. These roles both affect wayfinding performance and are affected by prior spatial ability, knowledge, and aspects of personality. Role-taking in groups has further implications for the design of both physical and digital navigation aids by improving what we know about the information needs of multiple people working in conjunction on a wayfinding task.

2.6 The Analysis of Social Interaction

A key dimension to this project is the analysis of social interaction between wayfinders. When moving from an individual to a dyad or larger group, there is increased complexity in the relationship with the spatial environment. No longer are we concerned only with a single person in relation to their environment, but the interaction between the people as well as between the people and the environment. This proves to be both a challenge and an advantage, as people working together socially on a task also tend to verbalize their planning and enactment strategies. Therefore this project provides a unique opportunity to investigate the use of common ground between two wayfinders working together. The qualitative approach to close investigation of social interaction that I apply in this project is *Conversation Analysis*.

2.6.1 Background on Conversation Analysis

The implications of this research are important and wide-reaching: successful navigation in groups requires successful social interaction, which may be the kind of interaction that supports cohesive and flexible planning. I use Conversation Analytic approaches in the microanalysis of how people suggest, agree upon, and coordinate their plans. In doing so, I find systematic structures in the way in which people make and respond to suggestions for route plans. I also describe how route cues are jointly established for later use by the dyad in navigation. A key feature of the Conversation Analytic approach to data collection [21, 22] is its concern with the study of talk-in-interaction, naturally occurring conversation as it unfolds within a socially-shared context. It often involves deep, close analysis of video recorded data of everyday interaction. Schegloff [23] asserts that although language is central to social life, language in action has not been a central focus in the discipline of sociology. Historically it has been left to linguistic study of 'pure' examples in language, rather than as it occurs in conversation. In sociological traditions, these conversational actions have often been overlooked in favor of investigating the 'real' agenda behind the actions (in line with the work of Goffman) – what they achieve for the involved parties versus how this is done.

More specifically for this project, Schegloff's work on socially shared cognition focuses on how people establish and understand shared knowledge with others in interaction. In his words, "to bring the study of cognition explicitly into the arena of the social is to bring it home again" [22, p. 168]. He states a need for more empirically grounded accounts of social actions and forms of social conduct by building a general inventory with descriptions of the actions used in talk-in-interaction. Challenges to this goal stem from interpreting or recognizing what constitute basic social actions. Interpretations of this kind have sometimes been advanced in the realm of anthropology, but anthropologists are often concerned with characterizing actions outside of one's *own* culture, whereas sociologists primarily examine action and interaction within one's culture or attempt to make more generalizable, non-culturally-specific claims.

Conversational action in the context of situated social navigation yields a wealth of opportunities for study along these lines. When two or more people are involved in the task of navigating together, they require not only to orient themselves with the physical environment but to coordinate their spatial knowledge and establish a common ground or "shared reality" within which they can work. In the example of route directions, Psathas [25] presented an account of "jump moves" used in verbal direction-giving episodes. A direction-giver may ask the recipient about their familiarity with certain places they may be expected to know; for instance, a major thoroughfare in town. The direction-giver is then able to constrain the search space for a starting-point in their directions by establishing an alternate place in common with the receiver. This acts like a jump between the initial starting point (such as where the receiver is currently located) to some secondary starting point, thereby skipping over a number of sequential steps in the route direction. This shows consideration for not only creating a route that works for getting from point A to B, but also plays a social role. The direction-giver does not describe to the receiver how to get to the secondary starting point, avoiding talk that repeats what is known by the recipient. This is not only a matter of efficiency but also demonstrates politeness by not questioning the competence of the recipient. Behavioral studies focused on paired navigation have also shown that people appear to be attuned to the navigational ability of their partner in terms of how they provide route directions (He, Ishikawa, & Takemiya [18], described above).

In Schegloff's [23] proposed list of elements necessary for the empirical account of an action, he includes: a formulation of the action with examples as well as problematic and/or "deviant" accounts, a grounding of the formulation in the participants' reality by providing some evidence that the interacting parties understand what the action is doing, and an analysis of what talk or conduct makes it that type of action. To begin to do so for the question of how people express navigational uncertainty, I collect instances of interaction in which this is seen to occur. Video recordings, in conjunction with GPS tracks, are analyzed in detail to form a characterization of how these expressions are made as well as why and when they occur. Using these, I provide an account of where and how this action is deployed within the situated conversation, for instance when the group is nearing certain decision points.

By looking at the talk immediately following a conversational action, it is possible to see whether participants understand what is being done. The subsequent talk to an action often recognizes the action by responding to it in some way. For the example of navigation, a co-navigator may see his or her companion pause walking at a juncture and use that opening to provide instruction. In this way, we see that he or she reads the pause as an expression of uncertainty. I cite specific examples of such interactions through the lens of CA in Chapter 5. Language is deployed flexibly in conversation, often achieving mutual understanding without necessarily being very precise in its references or specific in its meaning.

2.6.2 Relevance to this Project

The conversation analytic approach to understanding social interaction has the potential to explain valuable processes that people use when navigating to a destination with another person. By recording interaction as it occurs in the real world with the co-presence of other people, this approach to data collection and analysis can lend more ecological validity to studies than traditional lab-based structured navigation studies. Rather than setting people to a static task, it goes to where these real-world activities happen and investigates how people coordinate these activities together. Many behavioral studies are predesigned to collect certain expected behaviors, wherein the topics of observation are determined beforehand. CA, however, is focused on the deep analysis of natural conversation. There are a number of proposed advantages of using more naturally-occurring conversation as a source of empirical data. One prominent example is in spatial language. Employing CA methods, we have a better chance of learning how people form common ground between themselves, using place reference terms in conversation to establish a shared understanding of the environment [26]. It also has the potential to indirectly capture what is often left unsaid during communication; that is, what is assumed to be already known or shared between people, due to cultural context or other shared social categories.

Additionally, insights from conversation research show us that human interaction is structured. People do not pass information between themselves in some pure or direct transfer, but do so through speech as well as other modalities, which rely on our surrounding context for understanding (and are often imperfect and incomplete). For instance, in formulating a place reference, people are sensitive to their surrounding environment and use it in conversational practice to create shared understanding [26]. This analytic background has the potential to give us more ways in which we can understand how the project of real-world navigation is constructed and maintained (see Haddington [24] as one example). People clearly orient themselves not only to the spatial task of navigation, but to the social task of shared understanding. Goodwin [79] studies human language, cognition, and action in situations where multiple people carry out actions in concert with one another through talk, while attending to their environment and larger surrounding activities. His approach to studying cognition through environmentally-situated language and action would suit navigational tasks well. There are a number of important aspects of analysis left out by not relating to material environment, other reference spaces, and embodied action. The real-world interaction depends on all of these together because of its situation in a social context.

Video recording human activity poses its own set of methodological challenges but holds much potential for uncovering the social interactive processes at play between the actors. It allows for exploratory analysis of an interaction, meaning that unanticipated types of interaction can be recorded after the fact versus relying on real-time recording of predetermined behaviors by the researcher. There are notable caveats associated with coding video recordings as a form of data collection. For one, researchers run the risk of reactance during recording: people who know they are being observed tend to change their behavior [80]. This can be avoided if participants grow accustomed to being observed or if behavior is recorded in public places from far enough away. However, the effects of reactance may be minor, or may not undermine the validity of the data collection. The other main challenge is that video is incredibly time-intensive to transcribe and code, whereas more structured studies with *a priori* ideas about what to observe and record are faster and enable some or most of the coding to be done at the time of recording (at the expense of being able to return and code unexpected behaviors that may emerge). Related to this, controlled experiments are able to isolate the specific features of interest and thereby have the advantage of greater explanatory power. These factors, however, may be more readily identified and isolated in studies of individual navigation than in studies of group navigation, in which interdependent processes of communication may mask the variables of interest.

The practical advantages of video-recorded data over other data collection methodologies are numerous. The first is the benefit of having visual information to accompany verbal records. Rather than having only a transcribed account of the language used, for instance, to describe a route, it would be possible to return to the recorded data to identify referents that would be unclear from the statements in isolation. It is also possible to observe specific situated behaviors related to spatial orientation or planning, such as people pointing to features in the environment or symbols within the space of navigational aids like maps, useful in the study of navigation in real world environments [81]. Interaction happens in many dimensions beyond the modality of speech. Scholars have identified use of pause, eye movement, gesture, body positioning as other important sources of information in conversation and for researchers [79, 2]. These interactive modalities used in conversation may be able to tell us more about peoples' internal processes than people can mentally access through explicit reports such with the think-aloud protocols employed in the study by Hölscher et al. [14]. Video recording and close analysis of interaction has rarely been employed in navigational studies that would benefit from it. This approach provides an inroad to explaining the social processes that take place when two or more people work together to plan and execute a route plan.

Chapter 3

Route Planning and Navigation by Unfamiliar Dyads (Strangers)

The great majority of work in spatial cognition has taken an individual approach to the study of wayfinding, isolating the planning and decision-making process of a single navigating entity. The study I present here expands our understanding of human navigation as it unfolds in a social context, common to real-world scenarios. I investigate pedestrian navigation by pairs of people (dyads) who are unfamiliar with one another (strangers) in a novel, real-world environment. Participants collaborated on a task to plan and enact a route between a given origin and destination. Each dyad worked together to devise and agree upon a route to take using a paper map of the environment. They were then taken to the environment and asked to navigate to the destination from memory alone. I video-recorded and tracked the dyad as they interacted during both planning and navigation. These results examine explanations for successful route planning and sources of uncertainty in navigation. This includes differences between situated and prospective planning—participants often modify their route-following on the fly based on unexpected challenges. I also investigate strategies of social role-taking (leadership) within dyads;

this is further explored in Chapter 5.

3.1 Overview and Contributions

This research agenda furthers our understanding of social interaction in the context of wayfinding in several significant ways. First, using behavioral studies of pairs of people planning routes, I characterize the ways in which people coordinate shared knowledge of an environmental context and formulate an effective navigational plan in conversation. I also compare how this navigational plan is proposed ahead of time (prospectively) to how it is enacted in the physical environment (situatively). I demonstrate here the value of incorporating Conversation Analysis to understand common social actions and strategies in route planning. For instance, if leadership roles or spatial competence is established at this early phase, will that be carried into the execution of the navigation task?

Then, using the results from both the route planning and route execution phases, I formulate a generalized framework for how the navigation episode proceeds, focusing on the role of the route plan as executed in situ by the participants. This framework is informed by prior work in individual and group route planning and execution, including work by Allen [10], Denis, Pazzaglia, Cornoldi, and Bertolo [11], and others. I outline specific social roles taken by participants in these paired groups, taking as a starting point the characterizations of wayfinding roles previously proposed by scholars [20]. These potentially include, but are not limited to, roles such as leader and follower, or independent versus collaborative participation. However, following prior work in social psychology (as summarized for instance by Thibaut and Kelly [27]), larger groups are expected to demonstrate stronger differentiation in roles such as leader versus follower. At the level of the dyad, therefore, I expected to see more collaborative social interaction between the members, wherein both people contribute to wayfinding, though to varying degrees.

The question of how this then compares to groups larger than the dyad is still open for further study.

Additionally, I describe navigational performance by different dyads to explain how social interactive strategies contribute to success or failure in solving wayfinding problems, and to identify the occurrence of instances in which participants express indecision and uncertainty during wayfinding. I further investigate how this relates to navigational planning and execution by dyads within which the members already hold a prior social relationship with one another. Overall, this body of work makes a number of novel contributions to our knowledge of context-relevant, collaborative planning and situated navigation by pairs of people working together.

3.2 Method

This work investigates route planning and navigation by dyads in a novel environment. Participants making up the dyads did not previously know each other and had little or no prior knowledge of the study site. To investigate both prospective co-planning of routes and situated co-navigation, the study consisted of two phases: (1) the planning of a route between an origin and destination in a nearby neighborhood, done in a separate lab room, and (2) the subsequent navigation of the route within the environment. I integrate the conceptual and methodological research traditions of geography and sociology, which generally apply group-level analyses, and psychology, which conventionally examines the individual.

3.2.1 Research Questions

The research questions I address in this study are:

1. How do differences in sense of direction and personality among individual navigators relate to dyadic route planning and travel, examined both as overall characteristics of dyads and as differences between dyad members?

2. Do dyads' prospective planned routes through a novel environment differ from their routes as enacted *in situ*, and if so, how?

3. How do dyads coordinate their knowledge and behavior in a real-world environment to navigate efficiently, such as by adopting social roles within the dyad?

3.2.2 Participants

A total of 30 pairs of people (60 individuals) were recruited between February and November 2018 from a subject pool of university students enrolled in introductory Geography classes. However, as these courses fulfill several general requirements, very few students in the subject pool were Geography majors. Age of participants ranged from 18 to 33 years old, with the average being 19.5 years old (SD = 2.1). So that these results would not involve any effects of prior social role-taking, I tested pairs who did not previously know each other. I assessed prior familiarity by asking participants about it at the start of the study session. In most cases, the pair of participants only met for the first time during their participation in the research study ($n = 27$), though in a few cases they had briefly met in a classroom context but did not consider themselves to be more than acquaintances ($n = 3$). Therefore, we can disregard the effects of prior social role-taking in the dyads.

I attempted to recruit dyads evenly distributed between different gender pairings – female-female (F-F), male-male (M-M), and female-male (F-M) pairs – in order to capture a balanced sample that is more representative of all gender pairings. Though I am not attempting to draw a comparison between same or different gender groups, gender has been shown to have a reliable (but not absolute) relationship with spatial ability as well. A review of sex differences in spatial ability presented by Coluccia and Louse [62] shows evidence for sex differences in navigation ability, along with in other spatial abilities. I therefore expect that comparison across the three different gender pairings would capture the most variation, both in spatial performance and strategy, and in aspects of social interaction and role-taking. Each dyad was tested at a separate time (i.e. not concurrently).

3.2.3 Individual Difference Measures

I summarize the wide differences in peoples' individual abilities in terms of three factors important to this research agenda: sense of direction, personality, and gender. In doing so, I examine whether patterns of social interaction and wayfinding differ as a function of the dyads' overall levels of the factors, or as a function of the relative match or mismatch of these factors between members of the dyads.

Most participants completed both the Sense of Direction and the Big Five personality inventory on an online form that closely resembled the paper versions of these assessments. See Appendix A.3 for a copy of the forms used. In cases where participants failed to complete the online questionnaire ahead of time, paper versions of these assessments were provided upon meeting in the lab.

Sense of Direction (SOD). Directly relevant to real-world navigational ability is sense of direction (SOD), the ability to locate and orient oneself with respect to an environmental space. I assessed SOD with the Santa Barbara Sense of Direction Scale (SBSOD [49]), which asks people to rate their agreement with a variety of navigation-related statements, such as "I can usually remember a new route after I have traveled it only once" and "I have trouble understanding directions." Agreement is expressed on a

Likert scale from 1 (strongly agree) to 7 (strongly disagree), with positively worded statements reverse-coded so that a higher score indicates a better reported sense of direction. A summary of the participants' scores on the SBSOD scale are presented in Table 3.1.

Table 3.1: Means on SBSOD and Big Five Inventory for Individual Dyad Members ($n = 60$).

Measures	All Members [Range]	Females ($n = 43$)	Males ($n = 17$)
SBSOD	3.9 [1.6 – 6.6]	3.8	4.2
Extraversion	3.3 [1.5 – 5.0]	3.3	3.4
Agreeableness	4.0 [2.3 – 5.0]	4.2	3.8
Conscientiousness	3.6 [1.2 – 4.8]	3.6	3.4
Neuroticism	2.8 [1.4 – 4.6]	2.9	2.6
Openness	3.5 [2.1 – 5.0]	3.5	3.6

Personality. Personality may account for some of the differences in social interaction style, engagement with novel environments, and leadership. In this study, personality measures will allow me to account for whether pairings of people with certain personality characteristics (or combinations of personality characteristics) affect interaction, either during prospective co-planning of routes or during active, situated co-navigation. Prior work has attempted to delineate the complex relationship between personality factors and spatially-relevant measures such as SOD, starting with Bryant's seminal work [53, 57]. I assessed personality using the "Big Five" Inventory (BFI) [82, 60]. The Big Five factors are widely used and accepted, based on decades of research [83], and include the dimensions of *Extraversion*, *Agreeableness*, *Conscientiousness*, *Neuroticism*, and *Openness to Experience*. Respondents express their level of agreement with 44 statements on a 5-point Likert scale. For a given dimension, scores range from the lowest score of 1.0 to the highest of 5.0. A summary of our participants' scores on each dimension is presented in Table 3.1.

Gender. Gender has been shown to have a reliable relationship with aspects of spatial ability and style, including survey-based over route-based navigation [62, 84, 85].

Comparison across gender pairings therefore has the potential to capture considerable variation in spatial performance and strategy and in social interaction and role-taking. Scores on the SBSOD measure and the BFI measures of personality, grouped by gender, are shown above in Table 3.1. Dyads were fairly evenly distributed between female-female ($n = 15$), and female-male ($n = 13$) pairs. Unfortunately, there were very few male-male ($n = 2$) pairs, typical for the gender breakdown in the subject pool.

3.2.4 Materials

Test Neighborhood. The study site is a residential suburban neighborhood approximately 1.5 miles from campus (see Figure 3.1). Although there is public access, the neighborhood has only two entrances (to the north and west) and a number of traffic control measures (lower speeds and speed bumps), so it is not conducive to through-traffic. The layout is complex enough to pose a moderate level of wayfinding challenge, with a mostly circular street structure, smaller streets and cul-de-sacs branching off of the main access, and a central open space with interior footpaths. There is little elevation change throughout, so no locations provide visual access to the entire layout. This suburban neighborhood differs from a typical urban environment in that it has minimal visual differentiation in the form of landmarks and no regular street grid pattern. It differs from a more rural environment in that there are no long-distance vistas available within the neighborhood. These results may therefore be specific to this type of environment, leaving room to expand this research to a variety of environmental forms.

I selected a neighborhood that the pool of participants would likely be unfamiliar with, to ensure no advantage on the task based on prior knowledge. At the beginning of the study session, participants rated their prior familiarity with this neighborhood while looking at an overview map of the larger region. All participants included in the study rated their prior familiarity with the test neighborhood as either "very unfamiliar" or "unfamiliar," which meant that most had never previously been inside the neighborhood; those that had were further questioned to ensure this knowledge was minimal.

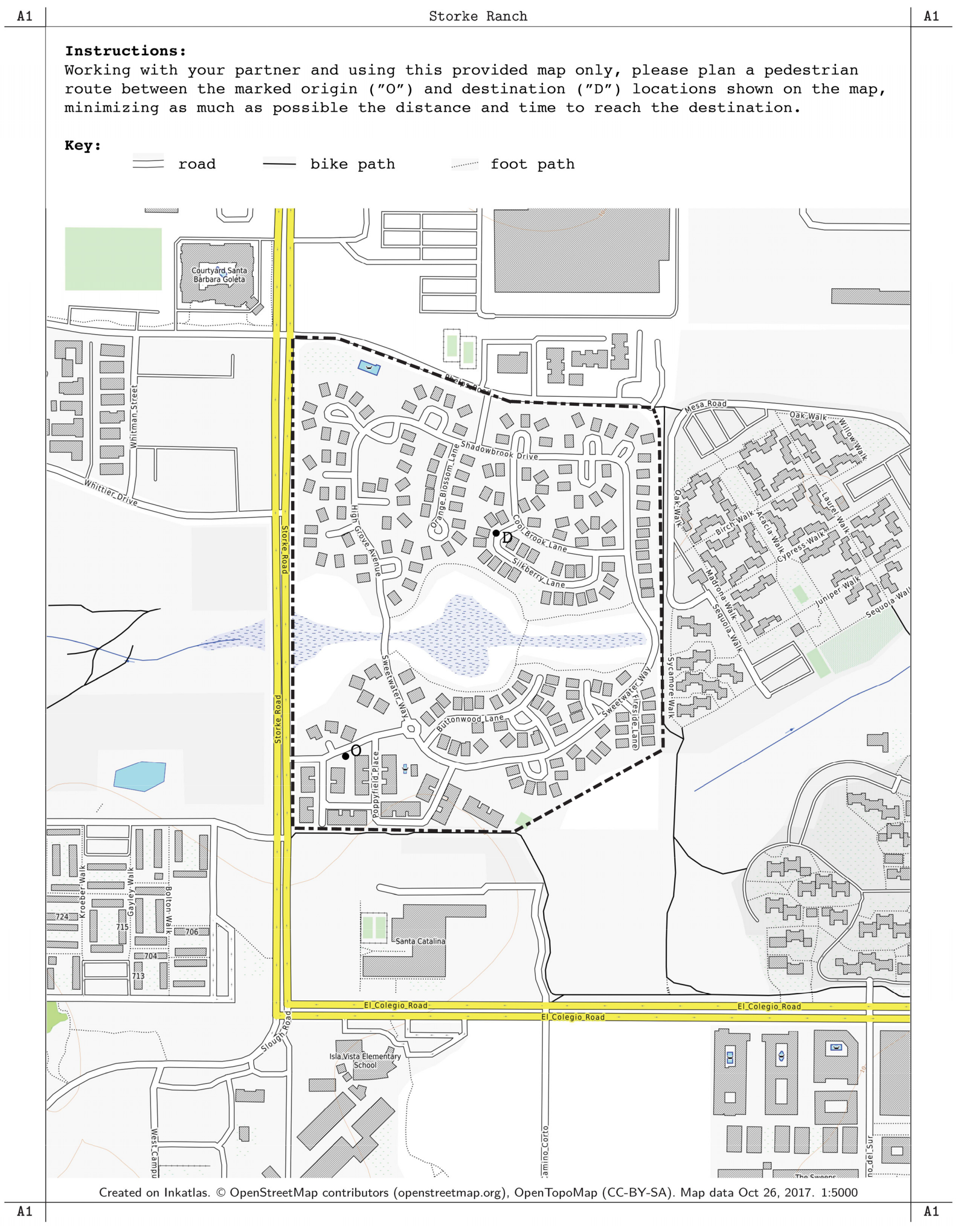

Figure 3.1: Map for planning with task instructions, marked origin and destination points, and key. The dashed line (not present on maps shown to dyads) shows the extent of the test neighborhood.

Map for Route Task. The planning phase involved a paper map of the study area, which is shown scaled-down in Figure 3.1. I created this map by selecting a custom area using the InkAtlas tool[1] from OpenStreetMap[2] base map data, including street, footpath, bike path, and building features, and editing it in Adobe Illustrator to include task instructions, a map key, and origin and destination locations for the task.

3.2.5 Procedure

The individual spatial ability and personality measures described above were administered using an online or pen-and-paper based questionnaire at sign-up. See Appendix A for the pre-study questionnaires and the full study protocol used for administration. The main data on route planning and navigation were collected in-person as follows:

Prospective Planning. The two members of a dyad met independently at the lab. They were asked to work together to plan a shortest-path pedestrian route between a given origin and destination in a neighborhood (previously unfamiliar to participants) located near campus, and told that afterwards they would be taken to the neighborhood to walk their route. Dyads were given the paper map shown in Figure 3.1 with the start and destination locations clearly marked. Participants were instructed to remember their planned route, as they would not have use of the map itself during their walk. Each dyad was given 10′ (10 minutes) to complete the task, including both deciding upon their route and committing it to memory.

While planning the route, social interaction within the dyads was video-recorded for later analysis. Coding the video recordings involved transcribing conversation and other interaction involved in the planning process, including gesture, eye contact, body position, commands and inquiries to the partner, and verbal references to the planned

[1]https://inkatlas.com
[2]Map data copyrighted OpenStreetMap contributors and available from www.openstreetmap.org

route, map, or environment. In the following analysis phase, video recordings were used to perform a conversation analytic (CA) assessment of methods used by one or both members to coordinate prior knowledge, adopt social roles within the pair, and make individual contributions to the paired planning process.

After planning, each member was separately asked to produce a drawing of the route ("route sketch") on a copy of the same base map and give a verbal description of the route they had planned with their partner. This was video-recorded for comparison within each pair (level of agreement within the dyad) and with the route as enacted by the dyad in the next phase (prospective versus situated navigation). Once the pair completed these route sketch and verbal description tasks, they were driven by the researcher to the start location for the situated navigation.

Situated Navigation. The dyad was then taken to the route origin within the task setting, where they were instructed to navigate on foot the planned route in the real environment. The navigation phase took place immediately following the planning phase, beginning at the route origin in the study neighborhood. Dyads were instructed to work with their partner to walk to the destination, minimizing the time and distance to reach the destination as best they could. Importantly, they were told they did not have to take the same route as planned in the first phase. Each participant wore a chest-mounted video camera (GoPro Hero 3+, a lightweight camera typically used for action sports) that recorded their speech, some of their hand gestures, and their approximate views. The researcher additionally observed, GPS-tracked, and video-recorded dyads using a handheld camcorder, but did not assist the dyads in any way to wayfind (i.e., gave no advice).

This phase of the study stopped either when the dyad reached and identified the destination successfully, unsuccessfully identified the destination point on three attempts (went to the wrong destination), or exceeded the maximum time allotted (30′). I counted it as an attempt when both members of the dyad identified to the researcher that they believed they were standing at the destination. The researcher then reported whether they had correctly identified the destination, and if not, how many attempts they had remaining. After this phase, the researcher walked the participants to a nearby location within the study neighborhood to individually complete a follow-up questionnaire noting their leadership, following, or collaboration during the task; any deviations from the planned route; and any other unexpected occurrences during navigation.

This synchronous, real-world navigation was compared to the participants' participation during the route planning task. This allows us to observe how the prospective route plan is made and then enacted in real-time during navigation, to see how participants interact in coordinating their anticipated route to the setting as it is experienced in person, and to make preliminary observations of how two people formerly unfamiliar to one another interact to complete a navigation task through a novel urban environment.

3.3 Results and Discussion

I first present overall task success for the dyads in the navigation task, relating navigational performance to difference measures for personality and spatial ability. Next, I summarize the effects of route selection and dyads' correspondence between their planned and enacted routes. Then I look more closely at the enactment of leadership within dyads, and examine a specific case of dealing with uncertainty during decision-making.

3.3.1 Navigational Performance

I use both time and distance as a measure of navigational performance on this task, as dyads were asked to minimize both when navigating to the destination location. Average total navigation time for all dyads in this study was $11' \, 29''$ and average total distance was 0.64 miles. Time was highly correlated with distance traveled, $r = .94$, $p < .001$, for all dyads. Generally, those dyads who took more time in navigation were those who walked further, but this is not a perfect correlation due to slight differences in time spent pausing and in walking speed. The initial measure of success was whether dyads navigated correctly to the destination location within three attempts and 30 minutes (30′). However, only one dyad failed to reach the destination within three attempts, and even they made all 3 attempts within 30′. This means 29 of 30 dyads reached the destination within three attempts. Of those who eventually found the destination, 26 dyads (87%) correctly reached and identified the destination on their *first* attempt.

Given the high eventual success rate, I distinguish the dyads who correctly reached the destination on the first attempt as "successful" and those who did not (including the dyad that never succeeded) as "failed." All 4 failed dyads were female-female pairs. The average navigation time by the successful dyads ($n = 26$) was 9′ 48″ ($SD = 4′ 05″$), the shortest lasting 5′ 10″ and the longest 22′ 55″. In contrast, the failed dyads ($n = 4$) took on average 22′ 28″ total, but averaged 14′ 06″ to their first (incorrect) attempt.[3] Successful dyads also traveled a shorter distance during navigation, averaging only 0.58 miles, as compared to failed dyads, who averaged 0.80 miles to their first attempt.

Though each dyad was allowed 10 minutes for planning prior to navigation, none required the entire time. The average planning time across all dyads was only 3′ 25″, and time for planning ranged from 1′ 15″ to 7′ 40″. Successful dyads planned for longer (average of 3′ 32″) than did dyads who failed (2′ 41″). Of course, a sample size of 4 is too small for meaningful significance tests, but it is still suggestive to note that failed dyads took 4′ 18″ longer and walked 0.22 miles further to reach their first attempted destination than did successful dyads, though successful dyads spent 51″ longer to plan.

[3]Subsequent comparisons involving time or distance traveled are based on time or distance to the first attempted destination, whether it was correct or incorrect.

3.3.2 Individual Differences

To assess sense of direction and personality for each dyad, I compared SBSOD scores and BFI scores on each dimension with navigational success using both the averages of members' individual scores and the differences between them (see Table 3.2 below). Again, for distance and time measures I use the distance and time to dyads' first attempt during navigation. I also report personality factors averaged from BFI scores for each dyad and their relation to distance and time to the first attempted destination. I found no reliable correlations between navigational time or distance and mean SBSOD or BFI personality factors.

The direction of correlation appeared to be positive for SBSOD, meaning higher SBSOD scores (suggesting better average sense of direction) may have related to travelling longer distances and taking more time to navigate (poorer performance). Comparing successful dyads to failed dyads, I find that mean SBSOD scores for successful dyads were actually 0.6 points poorer than for failed dyads. However, we would require a larger sample to verify these interpretations. This suggests the navigational advantage of better individual sense of direction scores may not apply at the dyad level due to the influence of social interaction. For instance, differences in personality may cause a dyad to have issues reaching consensus in their navigational decisions even where each individual may have a generally good sense of direction.

For further comparison, I assessed individual difference scores in terms of their mismatch between dyad members. I did this by calculating the absolute differences between members' scores on each measure (shown in Table 3.3 above). Although not quite reaching significance, dyads with greater differences in the members' SBSOD scores appeared to travel a shorter distance (r = -0.24, p = 0.19) and take less time (r = -0.29, p = 0.12) to their first attempt. This is consistent with the notion that having a member

Table 3.2: Means on SBSOD and Big Five compared with Navigational Performance.

Measures	All Members [Range]	Correlation with Distance	Correlation with Time
SBSOD	3.9 [1.6 – 6.6]	.14	.20
Extraversion	3.3 [1.5 – 5.0]	.11	.04
Agreeableness	4.0 [2.3 – 5.0]	-.15	-.13
Conscientiousness	3.6 [1.2 – 4.8]	.15	.15
Neuroticism	2.8 [1.4 – 4.6]	.13	.18
Openness	3.5 [2.1 – 5.0]	-.12	-.14

Table 3.3: Difference Scores on SBSOD and Big Five compared with Navigational Performance.

Measures	All Members [Range]	Correlation with Distance	Correlation with Time
SBSOD	1.3 [0.2 – 3.7]	-0.24	-0.29
Extraversion	1.0 [0.1 – 3.5]	0.33	0.32
Agreeableness	0.6 [0.0 – 2.0]	0.10	0.09
Conscientiousness	0.8 [0.0 – 2.4]	-0.24	-0.20
Neuroticism	0.9 [0.0 – 2.0]	-0.06	-0.13
Openness	0.7 [0.1 – 1.9]	-0.14	-0.11

with better sense of direction helps the dyad navigate more effectively, but especially when the other member is content to accede decisions to the member with better sense of direction (suggested by work such as He et al. [18]).

For personality, I found marginally significant correlations between difference in Extraversion and navigational performance ($r = 0.33$, $p = 0.07$ for distance and $r = 0.32$, $p = 0.09$ for time). That is, dyads with greater difference in members' Extraversion tended to travel longer and take more time navigating. I speculate that this could relate to leadership conflicts in groups with differing Extraversion; leadership is examined below. Differences in dyad members' personality scores on the other dimensions did not appear to correlate with performance. This points to the need to further investigate strategies used by dyads in planning and navigation that could contribute to success.

3.3.3 Adherence to Route Plans

I analyzed route plans as drawn and described by dyads and found high agreement within pairs. Most dyads ($n = 23$) agreed completely on their route plan, with each person reporting the same route as their partner in the individual descriptions of the route via the route sketches and verbal descriptions. In the 7 cases where they drew or described different routes, those routes had only a slight divergence (such as taking the first turn rather than the second onto the same street). In 3 cases, dyads prospectively planned a main route and an alternate route, and both members reported the two routes.

Figure 3.2: Five most popular route plans.

Figure 3.3: Overlay of all enacted routes.

A map displaying the five most commonly-planned routes by the dyads in this study is presented in Figure 3.2. These plans were compiled from the route sketches and checked against the video-recorded descriptions. Route plans not shown were minor variations on those shown, and were described by only 1 or 2 dyads in the study. Labels given to the planned routes are Route A ($n = 12$, shown in blue) which goes all the way around on the main road, Route B ($n = 7$, in green) which takes the footpath, Route C ($n = 4$, in yellow) which plans a shortcut through a place where it is not possible, Route D ($n = 7$, in orange)[4] which takes the footpath and anticipates the shortcut, and Route E ($n = 4$, in red) which takes the footpath and passes by the shortcutting opportunity.[5]

Dyads were instructed to take the best possible route to reach the destination location and not bound to follow their originally planned route. They therefore had the option of taking alternate routes or shortcuts but were not primed by the researcher to look for them. To measure the match between planned and enacted routes, I compare dyads' descriptions of routes during the planning phase with their recorded tracks of routes walked in the navigation phase. I processed minor noise in the GPS tracks by snapping the tracks to the road and path network using ArcGIS Desktop 10.6, while retaining any backtracking or significant divergence by comparing the tracks with the video recordings. In cases where the tracks were of poor quality or failed to record properly, routes were traced by hand based on the video recording only.

An overlay of all traveled paths by dyads during the navigation phase is shown in Figure 3.3 above. Darker colored lines represent segments that more dyads walked on; lighter colored lines are less-traveled paths. The most popular routes included the northern segment of the footpath and the main road running counter-clockwise through the neighborhood. Therefore, spatial strategies in this study appeared to sort into two main groups, those dyads taking the footpath and those following the main road.

To compare actual traveled distance to distance of the planned route, I computed a ratio of the distance of the route taken divided by the distance of the planned route:[6]

$$\textit{Distance Ratio} = \textit{Distance of Enacted Route} \,/\, \textit{Distance of Planned Route}$$

With this ratio, 0.5 represents a dyad who walked only half as far as they had planned,

[4] This is the shortest possible (legal) route.

[5] Numbers do not sum to 30, as some dyads reported two alternate plans.

[6] In cases where the dyad decided on and reported more than one route option, the distances of those planned routes were averaged.

such as by taking a shortcut; 1.0 represents a perfect match, where the dyad walked the same distance as the planned route (though not necessarily following the same route); 2.0 represents a dyad who walked twice as far as planned; and so on. The resulting ratios ranged from 0.67 to 4.33, with an average of 1.34 ($SD = .75$); this mean is significantly longer than 1.0, $t(29) = 2.49$, $p < .01$. Dyads thus walked longer overall on the enacted route than they had planned to walk, with one walking a distance over four times as long.

From participant responses to the follow-up questionnaire, I find that many were conscious of deviation from their original plan. In half the dyads ($n = 15$), one or both members mentioned taking a different path. Their explanations attribute these deviations to a variety of causes, which I categorized as "lost", "alternate", or "shortcut". The question posed was: "Did you and/or your partner take a path that was different from your planned route in any way? Describe if so." In order of declining frequency, dyads explained deviations as due to:

- **Lost** ($n = 8$): Experiencing unexpected problems, such as disorientation, turning the wrong way, or overshooting. Example: "Yes, we weren't sure about a few of the turns and overshot them so we had to backtrack."

- **Alternate** ($n = 4$): Taking a planned alternate route based on decisions during active navigation. Example: "We had 2 paths planned out. We found out that the plan A doesn't work, so we took the plan B."

- **Shortcut** ($n = 3$): Recognizing and taking a shortcut to the destination. Example: "Yes, instead of going all the way up the footpath we discovered a shortcut."

Overlap between Planned and Enacted Routes. To further compare prospectively-planned routes to routes enacted during navigation, I defined route overlap using the recorded routes and route plans as coded in our GIS. For each dyad, I extracted the overlapping segments between the enacted and planned routes using the ArcGIS Intersect tool. I then calculated route overlap by dividing the total distance of the overlapping segments by the distance of the route as actually walked by the dyad:[7]

$$\textit{Route Overlap} = \textit{Distance of Overlapping Segments} \,/\, \textit{Distance of Enacted Route}$$

In cases where dyads took the route they planned without any deviations, planned and enacted routes completely overlap (100%); in cases where dyads took completely different routes, overlap is 0%. In this study, percentage route overlap ranged from 100.0% to 11.9%; the average across all dyads was 69.1% (SD = 32.4%). One third of all dyads (n = 10) followed their route exactly as planned and reported with 100.0% overlap. Route overlap correlated negatively with time to first attempt, $r(28)$ = -0.59, $p < .001$, and with distance to first attempt, $r(28)$ = -0.48, $p < .01$, suggesting that dyads reached their first attempted destination more quickly and directly if they more closely followed their original plan. Route overlap was also marginally related to average SBSOD, where dyads with better sense of direction followed their planned routes less closely (r = -0.31, p = .095). Navigational performance therefore differed not only in total time and distance of travel, but also in terms of directness (as a result of more or less adherence to route plan).

Route Selection Strategy. The particular route selected during the planning phase appears to be the strongest predictor of whether or not dyads successfully reached the destination without getting lost. The most common route choice, Route A (refer back to Figure 3.2), involved taking the main road counter-clockwise through the neighborhood and included the fewest number of turns. Correspondingly, the dyads who planned this

[7]Where two different routes were described by dyads after planning (such as the case above where the dyad "had 2 paths planned out"), the planned route more closely matching the enacted route was used to derive the overlapping segment.

route were more likely to closely follow it ($n = 12$, average 89.0% overlap) than were dyads who planned other routes ($n = 18$, average 55.8% overlap); they were also more likely to follow the route exactly without going off course (9 of 12 dyads). There were no gender differences between those who took this route versus other routes.

Review of the video recordings made during planning show that some, but not all, dyads explicitly decided to take a route with fewer turns because it was easier to remember and held less risk of getting lost. This may point to the influence of route simplicity on navigational success. More complex routes have more turns to remember (or misremember), making them inherently more difficult to follow in a task that did not allow much opportunity to rehearse the planned route. Additionally, with more decision points to recognize, there is greater chance of travelers missing a cue in the environment while navigating *in situ*.

3.3.4 Social Leadership and Decision-Making

In their follow-up questionnaire, individuals were asked (separately) to state who acted more as the navigational leader during the task. Of the 30 dyads, 18 agreed that "neither was clearly leading more," 5 agreed that "one was leading more," and in the remaining 7, the two members disagreed about leadership. In the 5 dyads where one member claimed they were leading more, the partner agreed. Interestingly, in all 7 of the 'mismatch' cases, one person claimed "neither was clearly leading more" while their partner claimed that the first person was leading more. Perhaps people are hesitant to claim that they are leading more—that it is more socially acceptable to claim equal collaboration in the dyad rather than assert leadership (at least in the context of dyads whose members did not formerly know one another). This highlights a shortcoming of self-assessment; I follow up with this below by coding conversational behaviors to assess leadership and following versus collaboration in navigation.

Individual and Dyad-Level Differences. At the dyad level, Conscientiousness significantly differed between the 12 groups with a stated leader and those 18 without ($t(17) = 2.17$, $p < .05$). Those dyads with a self-reported leader/follower dynamic had an overall lower score (0.4 less) on Conscientiousness than those who reported a collaborative dynamic, and tended to have a larger mismatch (1.0 difference) between dyad members' Conscientiousness scores. No other individual difference measure appeared significant. I also looked at individual-level leadership scores[8] in relation to SOD and personality, and found no significant relationships.

Although Conscientiousness was significantly related to leadership at the dyad level, individual scores on Conscientiousness did not correlate with a tendency for an individual to lead. To not see effects of Extraversion and possibly SOD seems surprising, since I expect these differences to relate to the emergence of a leader within a group; for instance, Judge et al. [56] showed Extraversion to significantly relate to leadership. The adoption of leadership roles is likely to be context-specific: navigational leadership may be more likely to express itself in a larger group, where there is more potential advantage to having a strong leader and potentially cumulative inefficiency in considering each members' suggestions.

Talk During Navigation. As another measure of leadership versus collaboration in navigation, I examined talk during navigation and calculated a ratio of navigationally-relevant talk between the two members of each dyad. In the exploratory assessment of the collected video-recordings, I noted that if one person made most of the wayfinding decisions, that person generally spoke more about the navigation than their partner, who affirmed or accepted their partner's suggestions. In dyads that looked to be more collabo-

[8]Scores were assigned wherein stronger reports suggesting a given member was leading corresponded with a higher score: "0" for those who reported their partner led, "1" for each if both agreed neither was leading more, and "2" for those who claimed to lead or were identified by their partner as leading.

rative in their decision-making, this was observed as more of an equal exchange, with both partners discussing their available options and neither "dominating" the conversation. To quantify these observations with the transcribed video recordings of the navigation task, I summarized the total time each member contributed navigationally-relevant talk to the conversation. This provides a high-level view of comparative participation in the wayfinding, as another indicator of leadership.

Using all transcribed talk for each pair during navigation, I filtered out only the navigationally-relevant talk. Navigationally-relevant talk included all talk relevant to decision-making, identifying landmarks, remembering the route plan, or commentary on the current physical environment or the route. I excluded "getting to know you" talk, casual chat about interests, classwork, or weather, and anything that did not appear to contribute to wayfinding. I calculated a "talk ratio" equal to the duration of relevant talk by the partner who contributed less to the wayfinding divided by the duration of relevant talk by the partner who contributed more. This resulted in values between 0 and 1 for each dyad, where values closer to 1 would describe more equal durations of relevant talk between the members, a value of 0.5 would represent a case in which one member talked twice as much as their partner, and values closer to 0 would describe situations where one member dominated most of the relevant conversation. For these 30 dyads, these talk ratio values averaged 0.71 and ranged from a pair in which one person talked almost four times as much about the navigation as their partner (0.28) to a pair which was virtually equal (0.97).

Talk ratios corresponded with self-reported leadership, where dyads with a clear leader averaged a talk ratio of 0.65 and those who did not report a clear leader averaged 0.76. These means were significantly different, $t(21) = 2.1$, $p < .05$, meaning those who did not report leadership within the dyad did indeed have more equal durations of relevant talk than those with a reported leader. Especially in dyads with less collaborative talk ratios, the reported leader was consistently the one who talked at greater length over the entire task, with most navigation talk consisting of directives by the leader and often simple clarifications or affirmations by the follower. This suggests either that navigational leadership in a dyad is indeed associated with a less equal ratio of relevant talk, or that a less collaborative talk ratio gives the impression of leadership even where there is none.

3.4 Summary and Conclusions

This first study in my dissertation work makes a contribution to the empirical evaluation of wayfinding by explicitly considering social interaction. I present a comprehensive account of dyads working together to plan a navigational route through a new environment, then working together within a situated context to enact the planned (and sometimes misremembered) route. This scenario exemplifies *strong synchronous* social wayfinding in the framework by Dalton et al. [17], as dyad members directly interact with one another to make wayfinding decisions and accompany one another during the task in real time. This is one of the few empirical studies to date that has done so; others that have looked at strong synchronous wayfinding have generally used remote methods of communication [18, 20]. As stated above, there exists a body of work that looks at situations of asynchronous wayfinding (such as providing route directions [11]), but I also believe complementary work that would support this research agenda would focus on weak wayfinding scenarios, in which people follow social cues indirectly provided by others.

In these results, navigational performance did not seem to relate to gender pairings within dyads, though I recognize that the small number of male-male pairs in this study is a shortcoming. I believe that future studies focused on comparing different gender pairings during social wayfinding would make a valuable addition to the spatial cognition and navigation literature. Performance here also did not relate much to the average sense of direction or personality scores of the dyads, suggesting more in-depth interactional analysis is necessary to determine the social contributions to successfully wayfinding in pairs. Difference scores on sense of direction and personality measures between the dyad members showed modest and marginal relationships with performance: Dyads with greater difference in members' SBSOD scores navigated more quickly and for less distance, while dyads with greater difference in Extraversion scores navigated more slowly and for greater distance.

Most dyads walked further than planned, demonstrating challenges of accurately enacting a route plan *in situ*. The specific overlap between planned and enacted routes was nearly 70% and correlated strongly with time and distance walked to first attempt. In general, dyads who chose the simplest possible route to the destination were most likely to accurately walk the planned route. The cost associated with getting off-track when taking a complicated route reduced the advantage of planning a shorter route. Although selecting the simplest route to walk appeared to play a role in navigational success, dyads had various spatial and social strategies at their disposal to deal with uncertainties.

Self-reported leadership within dyads did not relate to individual Extraversion, but dyads with higher Conscientiousness did tend to work more collaboratively during navigation. However, as self-report falls short of assessing actual leadership verbalizations and other behaviors, I also looked at individual members' contributions to navigation during the task as a "talk ratio" and found that navigation-related conversation was indeed more one-sided in dyads with a reported leader-follower dynamic.

Detailed Conversation Analytic (CA) investigations into dyadic decision-making processes during navigation as described in Chapter 5 help illuminate the strategies employed in successful versus unsuccessful navigation. This is explored further in the following chapters. As an example and justification for this approach, I presented a detailed transcript of the interactions between the members of one dyad, suggesting that disagreements and miscommunications are an important source of uncertainty and contribute to poor navigational performance. Studying social navigation elucidates how people share knowledge in a task-oriented setting specific to wayfinding, establish social roles like leadership within groups, and deal with common challenges.

This study focused on dyads without prior familiarity with one another, but I acknowledge that social interactive aspects relevant to navigation may be more pronounced in dyads with prior familiarity. The next chapter presents a study in which dyads with existing social relationships (friend dyads) participate in a similar planning and navigation task. Whether accurate or not, existing notions about others' relevant navigational abilities should plainly influence group interaction. Established dyads are likely to have established patterns of interaction relevant to the domain of navigation and are likely to feel comfortable enacting those roles, so leadership may be more clearly expressed in such a comparison. Additionally, I use the video-recorded interactions to produce a collection of specific conversational actions relating to navigational leadership across dyads, to form the basis of a generalizable account of how this type of leadership is enacted socially. As follow-up to these two studies, I also make a direct comparison between dyadic and individual navigators, to help elucidate differences in planning and dealing with uncertainty when one is working alone versus with others.

3.5 Permissions and Attributions

The content of Chapter 3 and relevant sections of the appendix is the result of work in collaboration with Crystal Bae and Daniel R. Montello. This work has been presented at the Conference on Spatial Information Theory (COSIT) 2019 and has appeared in the COSIT 2019 conference proceedings [86]. This work is licensed under a Creative

Chapter 4

Route Planning and Navigation by Familiar Dyads (Friends)

In this chapter, I present the results of Study 2 and draw comparisons with the results of Study 1 (presented in Chapter 3). This second study looks at familiar dyads, or pairs of friends, in the same task environment as in the first study, performing route planning and pedestrian navigation of a route through a novel urban environment. This further investigates coordinated spatial learning and planning as prospectively planned and as it occurs in-situ by dyads who are formerly acquainted and in an established social relationship with one another. By explicitly assessing the effects of prior social relationships, I ask how familiarity with one's wayfinding partner impacts dyadic planning and navigation processes. The urban environment used is the same setting used in Study 1 and the task is nearly identical to that in Study 1, for comparison across stranger and friend dyads. Each dyad was tasked with planning a route with their partner from the origin to the destination location using an area map, producing individual route sketches and verbal descriptions of the route, then brought to the test location and asked to navigate together to the destination from the origin location. Participants were video-recorded during the planning and navigation phases.

4.1 Overview and Contributions

The focus in this study is on the impact of an existing social relationship (prior friendship) on the act of social role-taking and following in a paired interaction. Similarly to Study 1, this study explores how people perform prospective route planning as well as real-time, adaptive planning during situated navigation. It differs from Study 1 by following participants in a more ecologically-valid social scenario, in which partners are known to one another, exposing navigational and interactional differences as a result of prior relationships between the members of each pair. Real world navigation is likely to more often occur among established dyads or social groups, rather than pairs or groups of strangers. I hypothesize that dyads who have an established social relationship with one another may have more accurate preconceived notions of the members' relative spatial navigation ability. Established dyads are also more likely to understand and hold expectations of their communicative styles, social roles, and overall decision-making processes. They may additionally be more comfortable enacting either leader-follower or collaborative social roles within their dyad, so we may see clearer expressions of leadership.

I again employ Conversation Analysis to understand common social actions and strategies in route planning. In particular, I am interested in the impact of existing social relationships on dyads' role-taking during navigation and approaches to problem-solving during wayfinding that consider prior knowledge of one's partner. For instance, if the members of the dyad have prior knowledge of one another's spatial competence, does this necessarily make wayfinding communication and navigational performance more efficient for dyads? This qualitative assessment will allow me to identify the contributions to successful navigation that emerge from the social interactive aspects of the task.

Overall, this work contributes to our understanding of collaborative planning and navigation in an environment with high ecological validity, both in terms of the task environment and the social scenario. This can also have broader applications to general group decision-making research in psychology and sociology, and can inform the design of navigational aids, signage or wayfinding systems in built environments, or navigational support systems for use by multiple people.

4.2 Method

This study contributes to our understanding of route planning and navigation by dyads in a novel environment. The participants in this study were asked to sign up with a friend but, as before, had little or no prior knowledge of the study site. The two phases of the study mirror the task in the previous study (described in Chapter 3): (1) the prospective, in-lab planning of a route between a given origin and destination in a nearby neighborhood using a paper map, and (2) the subsequent navigation of the route within the real-world environment.

4.2.1 Research Questions

Relating to the research questions posed in the previous study described in Chapter 3, I further explore the influence of existing social relationships in the wayfinding context. In this study, I specifically address the following questions:

1. How much do similarities or differences in sense of direction or personality among individual friends contribute to successful route planning and navigation?

2. How do pairs of friends plan and enact wayfinding routes differently than do pairs of strangers?

3. In what ways do friend dyads carry out social roles in wayfinding that reflect their prior knowledge and experience of each other?

4.2.2 Participants

After the conclusion of data collection for the first study, another 30 pairs of people (60 individuals) were recruited for this study from a subject pool of university students enrolled in introductory Geography classes. Each participant signed up with a friend that they reported knowing for at least one year (12 months). None of the participants in this sample of participants had prior experience participating in the first study. Similarly to the previous study, very few students in the subject pool were Geography majors. The age of participants ranged from 18 to 25 years old, and the average across all 60 participants was 19.1 years old (SD = 1.4 years). The gender pairings in the study were also similar to the first study, with 13 female-female (F-F) dyads representing 43.3% of the sample, 14 female-male (F-M) dyads representing 46.7% of the sample, and 3 male-male (M-M) dyads representing just 10% of the sample. When the study site was described and shown to participants on an overview map, all 60 participants claimed to be either "very unfamiliar" ($n = 54$) or "unfamiliar" ($n = 6$) with the study environment, as measured on a 5-point scale ranging from "very unfamiliar" to "highly familiar." Therefore I have no reason to believe that prior familiarity with the spatial environment affected performance on the task.

Length of friendship in each dyad and prior familiarity with one another was assessed at the start of each session. Each dyad was asked how long they had known each other in years or months. In several cases the dyads' most precise estimate of the length of the friendship could only be provided in years or half-years. The average length of friendship in years across all 30 dyads was 3.3 years (SD = 3.1 years). Dyads who had known each other for less than one year were not included in the study. Prior familiarity was asked with a 4-point response scale which ranged from "acquaintances" to "best friends or romantic partners" (note that strangers were not included in the study, so it was not presented as an option). In most cases, the members of the dyads ($n = 28$) considered each other "friends," "best friends," or "romantic partners." For the other two, the members of one dyad did not consider each other "friends" but only those who spent "occasional time together"; and the members of the other dyad considered each other somewhere between those who spent "occasional time together" and "friends." However, future studies of this nature should also ask more specific questions about whether pairs have prior experience travelling together, as this would be more relevant to the specific task.

4.2.3 Individual Difference Measures

I first report mean scores on the Santa Barbara Sense of Direction (SBSOD) and Big Five Inventory (BFI) measures of individual differences. See Table 4.1 below.

Table 4.1: Means on SBSOD and Big Five Inventory for Individual Dyad Members ($n = 60$).

Measures	All Members [Range]	Females ($n = 40$)	Males ($n = 20$)
SBSOD	4.0 [2.0 – 6.6]	3.9	4.4
Extraversion	3.4 [1.4 – 5.0]	3.5	3.2
Agreeableness	3.8 [2.6 – 4.9]	3.9	3.7
Conscientiousness	3.4 [1.8 – 5.0]	3.5	3.2
Neuroticism	3.0 [1.1 – 5.0]	3.1	2.8
Openness	3.4 [2.3 – 5.0]	3.4	3.4

Individual difference measures were overall similar to the individual participants included in the previous study (see 3.3), and did not significantly differ between females and males.

4.2.4 Materials

Much of the materials mirror those used in the previous study, described in Section 3.2.4. All measures were controlled to keep much of the study protocol the same as in the first. I again use the on-campus lab environment for the initial planning phase of this study. The study site is the same one used in the previous study, with the same origin and destination locations for the task, and the map used for planning is the same. The only differences in protocol are that participants signed up with friends and were therefore presented with a slightly modified scale when they were asked about their level of prior familiarity with one another, and the post-navigation survey questionnaire had modifications to some of the questions. Refer to Appendix B for the IRB consent form, full protocol, and forms used.

4.2.5 Procedure

The procedure for this study is modeled on and very similar to the procedure used in the previous study. See Section 3.2.5 or Appendix B for the detailed protocol.

One participant from each dyad signed up for a timeslot through an online departmental research pool, this time with the requirement to participate with a friend that they had known for at least one year. Each participant completed an online questionnaire which included the sense of direction and personality measures. Both the planning and navigation phases of the study mimic the previous study, the only difference being that participants were friend dyads rather than stranger dyads.

Once correctly reaching the destination or failing to reach the destination in the navigation phase, the dyad was led by the researcher to a nearby location in the study site in order to individually complete the follow-up questionnaire (see Appendix B). Two additional questions were included in this questionnaire that were not present in the

Study 1 (Strangers) questionnaire: one asking about their confidence in their partner's general sense of direction or navigation ability, and another confirming how long they have known their partner.

4.3 Results and Discussion

In this section, I present both the results from this study, which focuses on the wayfinding of pairs of friends, and the comparison with the results of the previous study, which focuses on the wayfinding of pairs of strangers. This allows me to investigate not only the behavior of successful versus unsuccessful friend dyads, but also what differentiates friends and strangers in both their prospective planning and *in situ* route execution.

4.3.1 Navigational Performance

I again use the success to reach the destination, navigation time, and navigation distance as measures of performance for the dyads in this study. Overall total time navigating for all 30 dyads averaged $9' \ 14''$ (9 minutes and 14 seconds), with a range from the shortest navigation time of $5' \ 25''$ to the longest time taken, $21' \ 30''$, and a standard deviation of $3' \ 49''$. Overall total distance averaged 0.52 miles, with a range from the shortest navigation distance of 0.36 miles and the longest distance of 0.92 miles, and a standard deviation of 0.13 miles.

Total navigation time was highly correlated with distance travelled, $r = .86$, $p < .001$. Similarly to pairs of strangers, this correlation was very high ($r = .94$ for strangers, as reported in the previous chapter). The correlations were not significantly different between friend dyads and stranger dyads ($z = 1.63$, $p = 0.10$, two tailed Fisher transformation). A weaker relationship between travel distance and time might suggest more pausing during navigation, potentially for dyads to revisit their plans, as opposed planning while continuing to move. However, when examining the pausing behavior based on the recorded GPS tracks (only available in full for 19 of 30 stranger dyads and 21 of 30 friend dyads), I find no significant differences between friend and stranger dyads in pausing or slowing down duration over the course of the navigation.

To compare the friend dyads in this study to the stranger dyads in Study 1, I find that friends travelled more efficiently than strangers overall. Friend dyads averaged shorter total distances than strangers (0.52 miles for friends, 0.64 miles for strangers, $t(58) = 2.05$, $p < .05$), but their difference in total time was non-significant ($9'\ 14''$ for friends, $11'\ 29''$ for strangers, $t(58) = 1.68$, $p = .10$). In terms of first attempts, friends travelled more directly (0.49 miles for friends, 0.61 miles for strangers, $t(58) = 2.24$, $p < .05$ for distance to first) and more quickly ($8'\ 14''$ for friends, $10'\ 22''$ for strangers, $t(58) = 2.18$, $p < .05$ for time to first) to their first attempted destination location than did strangers.

Using the same measure of success as in the previous study, any dyad who correctly identified the destination on their first attempt was considered successful. In total, 22 of 30 friend dyads (73%) reached the destination correctly on their first try. This is lower than the 26 of 30 stranger dyads (87%) who succeeded on their first try. Of the 8 dyads who failed to reach the destination on their first attempt, 4 were female-male pairs, 3 were female-female pairs, and 1 was a male-male pair.

Comparing the group means on both navigation and time for the friend dyads, I find that successful dyads travelled on average 0.48 miles and $7'\ 35''$ to reach their destination, whereas those who failed travelled on average 0.52 miles and $10'\ 01''$ to reach their (first) destination and on average 0.65 miles and $13'\ 48''$ *total*. Time taken by dyads to plan their route using a paper map in the lab ranged from $1'\ 00''$ to $9'\ 00''$. The average planning time for dyads was $2'\ 59''$, and this did not vary between those who were eventually successful and those who were not. It seems therefore that overall planning time for pairs of previously acquainted dyads did not impact success in the navigation.

Compared to the 26 successful stranger dyads in the previous study, the 22 friend dyads who were successful navigated on average for a shorter time and distance to reach their destination (0.48 miles and 7' 35") than the pairs of strangers in the previous study (0.58 miles and 9' 48"). See Figure 4.1 for a jitterplot of time and distance to first attempt for both successful friend dyads and successful stranger dyads. Differences between successful stranger dyads and successful friend dyads were significant both in terms of travel time ($t(34.98) = -2.5$, $p < .05$) and in terms of distance ($t(33.94) = -2.1$, $p < .05$). This means that of those who successfully reached the destination on their first attempt, stranger dyads took longer than friends and travelled further to do so. This occurred even though the friends did not have a higher SOD than the strangers (no significant difference in mean SOD).

4.3.2 Individual Differences

I next assess individual differences in terms of sense of direction and personality measures for friend dyads in this study. I compare individual difference measures (using both means and differences of scores) with navigational performance in terms of distance and time.

In Table 4.2 below, I present the mean SBSOD and Big Five scores for friend dyads alongside their correlations with distance and time to the first attempted destination. Although the correlations reported below do not reach significance, there are a few notable trends among these dyads with prior familiarity. First, it appeared that – as with stranger dyads – higher SBSOD scores may have been associated with taking *more* time ($r = .24$, $p = .21$) and travelling *longer* ($r = .34$, $p = .07$) to reach the first destination. Dyads with higher average sense of direction scores showed poorer navigational performance than

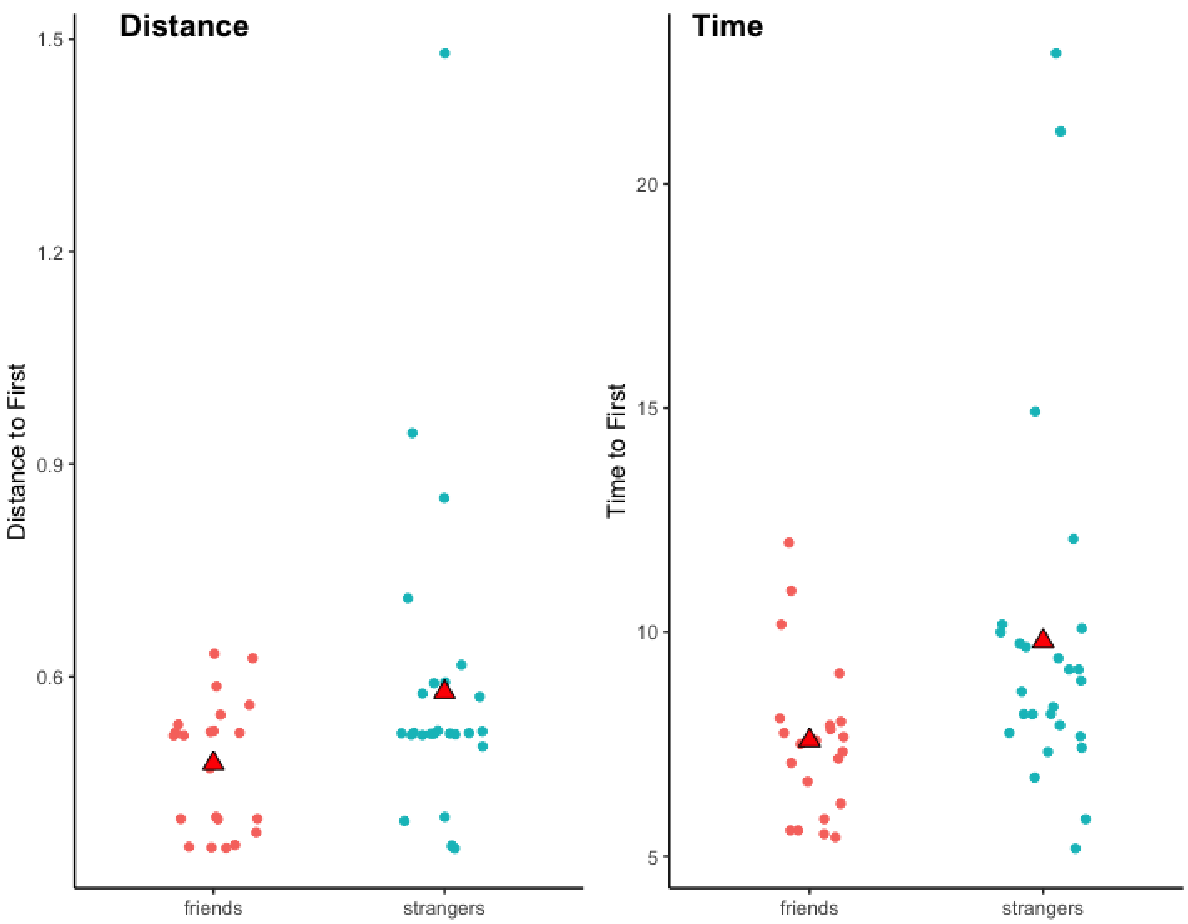

Figure 4.1: Jitterplot of Distance and Time to first attempted destination by successful dyads.

those with lower scores. This may be due to differences in route planning, such as those dyads with better SOD planning more complex routes. This negative correlation between sense of direction and navigational performance also appears to be a more pronounced effect in friend dyads than in stranger dyads, which supports the idea that those with more confidence in their sense of direction may select routes which appear to be more efficient, even if they are more complex to remember or recognize when in the environment.

Table 4.2: Means on SBSOD and Big Five compared with Navigational Performance (for Friend Dyads).

Measures	All Members [Range]	Correlations with Distance	Correlations with Time
SBSOD	4.0 [2.0 – 6.6]	.24	.34
Extraversion	3.4 [1.4 – 5.0]	-.07	-.04
Agreeableness	3.8 [2.6 – 4.9]	-.14	.07
Conscientiousness	3.4 [1.8 – 5.0]	-.30	-.17
Neuroticism	3.0 [1.1 – 5.0]	.05	.05
Openness	3.4 [2.3 – 5.0]	.13	.07

Length of friendship also had no significant effect on navigation time or distance. If such a relationship exists here, it would appear to be in the positive direction, with longer friendship related to better performance. Those dyads reporting longer friendships seemed to travel on average a shorter distance (r = -.20, p = .28) and for less time (r = -.28, p = .13) to reach their first attempted destination. Again, length of friendship in this sample ranged from 1 to 12 years of friendship with a mean of 3.3 years and standard deviation of 3.1 years.

I also assessed dyad members' differences in scores on SOD and personality, presented in Table 4.3 below, as I did previously for the stranger dyads. Although correlations with distance and time to first attempt are reported in the table, none of the below correlations reached significance in this sample. Here the only correlations that approached significance are dyad difference in Conscientiousness scores with time to first destination

(r = -.24, p = .19); and dyad difference in Openness to New Experience scores with distance to first destination (r = .28, p = .13). Rather than speculating further on these individual difference measures in isolation, it is more useful to consider strategies and approaches that dyad members used during the task and how these may be affected by individual personality and sense of direction.

Table 4.3: Difference Scores on SBSOD and Big Five compared with Navigational Performance (for Friend Dyads).

Measures	All Members [Range]	Correlations with Distance	Correlations with Time
SBSOD	1.3 [0.3 – 2.9]	.19	.05
Extraversion	0.8 [0.0 – 2.4]	.14	.10
Agreeableness	0.7 [0.0 – 2.3]	-.03	-.11
Conscientiousness	0.7 [0.1 – 2.1]	.08	-.24
Neuroticism	0.7 [0.0 – 3.4]	.07	.15
Openness	0.7 [0.0 – 2.1]	.28	-.06

4.3.3 Consideration of Routes

There are clear differences in how the friend dyads worked to plan their routes through the novel environment as compared to how the stranger dyads completed the same task. Overall, the 30 pairs of friends came up with and reported more unique routes than did the 30 pairs of strangers. Friend dyads also more commonly planned and reported alternative routes than did stranger dyads, meaning they were more likely to make contingency ("backup") plans. I suggest that this difference in planning relates to their performance success in the enacted navigation, which I report in detail in the following section.

It is likely that being a member of (and self-selection into) an already-established dyad facilitated communication between the dyad members, allowing them to discuss plans more easily and exert less social effort to do so. Therefore we see that friend dyads discussed more plans and may have exhausted more potential routing options before deciding they were done planning, despite taking about the same amount of time to plan (3' 25" for strangers; 2' 59" for friends; $t(58) = 0.90$, $p = .37$).

As with strangers, overall planning time for friends did not relate to navigational success in this study. However, looking at the numbers of routes considered by dyads, friend dyads in this study planned and reported a greater number of unique route plans. Overall, there were 16 unique route plans reported by the 30 pairs of friend dyads, versus only 9 unique route plans reported by the 30 pairs of stranger dyads. More unique routes reported as plans may indicate that friend dyads have more confidence in their own (paired) ability to carry out a complex route in a novel environment.

During the planning process itself, dyads with a prior social relationship also demonstrated more planning of alternative routes, rather than a commitment or explicit agreement on only one main route plan (as seen among stranger dyads). I find in the analysis of video recordings that members of friend dyads more often explicitly raised uncertainty about the "possibility" of carrying out suggested routes. This is most clearly shown through the Conversation Analysis examples that follows in Chapter 5. Most commonly, when one partner suggested cutting through an area not explicitly marked as a path on the map, the dyad pre-emptively considered alternatives to take in case the plan turned out to be impossible in the situated navigation. This suggests either that friends may be better able to imagine or visualize future problems during planning, or more likely that they are more likely to raise such issues in communication than relative strangers.

Indeed, there appeared to be less hesitation associated with friends with regards to raising potential problems with the suggested or agreed-upon route plans. Where strangers easily accept most suggestions by their unfamiliar partner, friends are more hesitant to do so. I posit this is because friends are better able to assess route plans as something *independent* from either partner; as a separate resource to consider together rather than as a signifier of either partner's competence as a planner or navigator. I provide further support for this through the qualitative microanalysis of conversational interaction in Chapter 5.

4.3.4 Correspondence between Planned and Enacted Routes

To compare distance travelled in the environment to the distance of the planned route, I again report the distance ratio as:

$$Distance\ Ratio = Distance\ of\ Enacted\ Route\ /\ Distance\ of\ Planned\ Route$$

This ratio would be equal to 1.0 if the enacted and planned routes match in distance, although it does not necessarily indicate use of the same path. The distance ratio between the length of the route enacted during navigation and the length of the planned route(s) averaged 1.22 for pairs of friends (compared to 1.34 for pairs of strangers). This is significantly different from a distance ratio of 1.0, $t(59) = 3.4$, $p < .005$, meaning dyads travelled further than planned. Although it suggests that friends on average followed their plans more closely, the difference between friends and strangers is not significant, $t(52.08) = -0.7$, $p = .49$.

To more precisely consider the overlap between the planned route and the enacted route, I again calculate the route overlap, or the adherence to the planned route during navigation, as:

$$Route\ Overlap = Distance\ of\ Overlapping\ Segments\ /\ Distance\ of\ Enacted\ Route$$

In the case of the friend dyads, average route overlap for all 30 dyads was 75.4% (SD = 31.0%) and ranged from 100.0% to 17.1%. This is very similar to the average route overlap for the 30 stranger dyads (69.1% route overlap; SD = 32.4%). However, this difference between route overlap between the dyads in the first study (strangers) and second study (friends) is not significant, $t(57.90) = 0.8$, $p = .44$. For friend dyads, there was a significant negative correlation between average SBSOD scores and amount of route overlap (r = -0.39, $p < .05$), but stranger dyads only showed a marginally significant negative relationship. This suggests that friend dyads with better sense of direction are less likely to follow their planned routes closely.

Over half of the friend dyads (16 of 30) followed their route exactly as planned, with 100% overlap, as compared to only a third of the stranger dyads (10 of 30). This supports the suggestion that friends were able to more closely follow and enact their original route plans, although they also had more plans available to them due to a more thorough consideration of possible routes. Route overlap again correlated negatively with dyads' time and distance to first attempt. As expected, those who more closely followed their reported plans took less time (r = -0.65, $p < .05$) and travelled a shorter distance (r = -0.31, $p < .001$) to the first attempted destination. It is therefore important to emphasize the role of planning in successful wayfinding.

Turning to the participants' self-report of adherence to plans, I find that the same number of participants (16 of 30) reported following their route exactly as they had planned it, with no modifications en route. For those who reported deviating from their plan, their responses appear similar to those of the stranger dyads in Study 1. Those negative responses to the follow-up question of "Did you and/or your partner take a path that was different from your planned route in any way?" were characterized as follows:

Explanations	**Study 1: Stranger Dyads**	**Study 2: Friend Dyads**
Lost	8	6
Alternate	4	4
Shortcut	3	4

4.3.5 Reported Leadership in Friend Dyads

In addition to following their routes more closely, friend dyads reported a leader-follower dynamic more often than did stranger dyads. In the survey filled out by individual participants after the navigation phase of the study, one or both members reported leadership by a dyad member in 70% of the friend dyads (21 of 30), as compared to only 40% reported leadership in the stranger dyads (12 of 30).

Alongside the more frequent reporting of leadership in dyads comprising friends, members of friend dyads were more likely to self-report their *own* leadership within the dyad even when their partner did not separately report the same (that their partner led). This happened in 5 of the friend dyads, and not at all for stranger dyads. It is unclear why this is so, but must relate to prior social familiarity, such as the beliefs that dyad members may hold about their partner's competence. I assert that prior beliefs held by participants about their wayfinding partners impacted their perception of the ongoing social actions, but it is an open question as to how much it did so. Alternatively, friends may generally be less shy about claiming leadership even if their partner may disagree.

4.4 Summary and Conclusions

In this study, I focused on dyads with prior familiarity with one another (friend dyads), hypothesizing that social interactive aspects relevant to navigation may be more pronounced in dyads with prior familiarity. This built upon the research questions posed in the previous study, described in Chapter 3, extending that study of stranger dyads to look at the influence of existing social roles in the wayfinding and spatial decision-making context. Specifically, I suggested that prior social familiarity and existing social roles may be carried into the planning and navigation tasks in terms of leading and following or collaboration between dyad members.

Again, like with the stranger dyads in Study 1, navigational performance did not directly relate to individual difference measures such as SBSOD and the Big Five Personality Inventory. Gender differences were inconclusive due to the uneven distribution of gender pairings across dyads in the study, but is further considered in the qualitative assessment. I found in this study that friend dyads travelled faster and for shorter distances to reach the destination than did stranger dyads in the previous study, and successful friend dyads were also more efficient than successful stranger dyads. This is in part because friend dyads considered and planned more alternative routes ahead of time, making them more efficient in changing course en route.

Next, in Chapter 5, I look more closely at the conversational practices of dyads during planning and wayfinding to determine some of the underlying patterns in communication and spatial coordination that aid dyads during navigation. Although more friends followed their plan exactly than did strangers, there were no significant differences in the degree to which friend dyads followed their planned routes as compared to stranger dyads. In terms of social role-taking, friends did indeed report leadership more often (in 70% of dyads) than did strangers (in 40% of dyads). Leadership is explored in more depth in the following chapter, section 5.3.

In the third study, which is described in Chapter 6, I look at how the study of dyads compares to individuals performing a similar task. This will help distinguish what role sociality plays in the act of wayfinding, such as with relation to the expression or suppression of uncertainty, collaborative decision-making, distribution of cognitive tasks, and differences in strategy use.

Chapter 5

Social Interaction in Wayfinding

In this chapter, I outline the most prevalent patterns of interaction and social strategies employed by wayfinding dyads during both prospective planning and situated navigation in the study environment. Wayfinding represents the planning and decision-making component of navigation, and could be among the most common, real-world domains of both individual and group-level decision making. Because we live and act in a social world, wayfinding is not a solitary process but is influenced by the actions of other people – even by their mere presence [17]. The interaction of dyads directly working together on a route planning task and the subsequent real-world navigation gives us insight into common sequences, strategies, and sources of uncertainty that emerge from both the social and spatial aspects of this type of interaction. The data used in this qualitative analysis is drawn from my collection of video-recorded interactions in which dyads were instructed to plan a route that they would then take together through a novel environment (the first and second studies of the dissertation, described in Chapters 3 and 4). The corpus comprises 3.2 hours of planning video and 10.4 hours of navigation video across both studies.

From the social interactive analysis of planning, I first focus on how members of the dyad perform sequences of suggesting routes, evaluating routes, and jointly deciding on a route plan (Section 5.1). During the planning process, social expectations and prior knowledge affect how plans can be proposed and their available responses. After outlining the sequential organization of making route suggestions, I look at challenges that dyads encounter in both the planning and the enactment of the wayfinding task (Section 5.2). Specific sources of uncertainty revolve around correspondence between the wayfinding aid (in this case, the provided paper map) as well as their individual and joint ability to carry out the plan (e.g. ability to remember the route or identify the decision cues). I also identify a practice that dyads use in situated wayfinding that I call *spatial bookmarking*. This is the practice of marking a reference point in the spatial environment to return to mentally for further planning or return to physically as the last known location.

From the social interactive analysis of navigation, I also assess the emergence of leadership and shifts in social roles throughout the process of situated wayfinding (Section 5.3). In terms of leadership, I find that changes in status revolve around displays of competence during the task. Taken all together, this chapter provides an account of many of the regularly occurring challenges and considerations in both planning routes with a map and enacting routes through a novel environment.

5.1 Route Suggestions during Planning

In this section, I investigate the structure of suggestion sequences as employed during navigational planning.[1] I apply Conversation Analysis (CA) to examine how dyads plan a route through a novel environment using video-recordings of pairs of participants planning together with a paper map. I assess the systematic structural characteristics of the suggestion sequences used to propose and respond to route plans. The basic structure of

[1] An earlier version of this section was previously published as a workshop paper [86].

the route suggestion sequence is presented, alongside collected examples that demonstrate the components of this structure. This is ongoing work that shows the potential of such an applied framework and poses several open questions for future analysis of verbal wayfinding planning processes.

All conversation is sequentially organized, in that communicative utterances are produced with reference to one another. The structure of how conversation is shaped sequentially involves turn-taking and sequence organization as its building blocks. *Turn-taking*, as described by Sacks, Schegloff, and Jefferson [87], involves the distribution and transitions of turns by speakers over the course of a conversation. The system of turn-selection is influenced by context, which can include speakers' social relationships and other ongoing considerations (such as the environmental cues or wayfinding task here). *Sequence organization* [88] describes the ordering of social actions and how turns are produced as recognizable sequences by its speakers.

Adjacency pairs are one aspect of sequence organization that is relevant here, referring to sequences that comprise two actions by separate speakers that are adjacently placed [89, p. 59]. The first pair pair (FPP) that initiates an action makes the second pair part (SPP) conditionally relevant. In other words, there is systematicity in the kind of SPP that is produced in response to the initiating FPP. For instance, if the first speaker asks a question, the second speaker is normatively expected to provide an answer – and if they do not, it is typically for the purpose of expansion or it becomes treatable as accountably "missing."[2] Several basic types of adjacency pairs have been identified in the literature, including question-answer sequences, assessment and acceptance or refusal sequences, and so on. Because this structure is observable and understood by all speakers, it provides coherence to talk in interaction. Scholars have also identified that adjacency pairs are not symmetrical (as referenced in Schegloff [89]): certain responses are either

[2] If there is no readily available account for a non-answer, the answer is treated as "relevantly absent."

preferred or not ("dispreferred") in interaction. Not only are some responses preferred or dispreferred, speakers recognize the distinction between the two and produce them differently in conversation.

Following what has already been set forth in the literature, I propose there is observable systematicity in the practice of how people make and respond to suggested route ideas. I present the simplest structure of proposing a new suggestion in a navigational planning task, then investigate commonly observed responses to a suggestion. I also pose a few open questions on the organization of suggestion sequences, specific to the context of wayfinding.

To assess social interaction during route planning, I apply these methods of analysis to the video-recorded interaction between dyads participating in the behavioral study described in Chapters 3 and 4. Relevant talk and gestures were transcribed manually by myself and several research assistants using the ELAN software developed by the Max Planck Institute for Psycholinguistics [90]. Transcription conventions are simplified from the guidelines in Sacks et al. [87] and Jefferson [91] and are described in Appendix C.1. The assessment of these transcribed videos was completed in conjunction with my research assistants, according to a coding guide as well as open qualitative discussion.

5.1.1 Route Suggestion Sequence

I begin with the least embellished form of a route suggestion sequence to observe what features of planning appear to be systematic across multiple cases. Route planning begins when there is a shared understanding of the task at hand: a mutual orientation to the origin and desired destination. In cases where the navigation is situated – where the participants are physically co-present and located at the place where they will begin their navigation – the origin point is usually assumed to be the current location [9]. As the participants are given the origin and destination point for this task, those are made explicit in the instruction.

The basic form of a route suggestion follows this structure:

- **(1) First pair part (FPP)**

  Speaker 1 proposes a new suggestion:

  - (a) opens,
  - (b) then proposes route suggestion,
  - (c) then ends and makes relevant an assessment of the suggestion at the transition-relevance place (TRP).

- **(2) Second pair part (SPP)**

  Speaker 2 responds by either:

  - (a) accepting the route suggestion,
  - (b) or presenting an alternative, with or without raising issue with the suggestion presented in the FPP.

5.1.2 Proposing a New Suggestion as a First Pair Part (FPP)

To explore the first step above in detail, I present representative excerpts to demonstrate how this is enacted in the given route planning scenario. Once the planning process commences, the first route suggestion may come in the first pair part (FPP) from either speaker, and is likely to be related to a number of factors (including but not limited to social and cultural norms and expectations, personality, and mood). However, the speaker who first makes a suggestion is putting themselves and their suggestion "on the line" to be critiqued or judged by the other person. The speakers display a clear orientation to this: The first speaker often does not simply launch directly into the suggestion but opens with a hedged introduction: "what if we..." or "I think..." or "I would..." It is also worth noting that in the interactions between stranger dyads, the speakers were previously unfamiliar with one another. However, within friend dyads, members of the dyad may have had previously established assumptions about who is meant to go first. In neither case were dyads given designated leadership roles in the task.

In Excerpt 1 below (see all excerpted transcripts in Appendix C.1), speaker A opens her suggestion,[3] using the hypothetical form "what if we": "what if we just go this way" (line 1), before launching into her suggested plan. Suggestions are made with an alignment towards their possible rejection, such as here in the form "we *could* do X" rather than "we *should* do X". This opens the possibility for the suggestion to be rejected or called into question by the partner; it is easier both for the second speaker to make a rejection and for the first speaker to accept the rejection.

Excerpt 1

```
01 A: what if we just go this way LOOK like right here ((tracing route on
02    map)) (.) and then just like stra::ight there (0.5)
03 B: ((nods))
04 A: right? th- that's sp- what's gonna be (.) straightforward
05 B: yeah (.) what's this though (.)
```

Another example of a hedged introduction to a first suggestion appears in Excerpt 2. Speaker A first begins with "I'm thinking maybe this way rather than that way" (line 1), doubly reduced from commitment through the addition of "I'm thinking" and "maybe". She defends her reasoning, "that way just seems longer to me" (lines 1-2), justifying the suggestion of that particular route over other visible options.

[3]The use of gendered singular pronouns here is not meant to imply that the following analyses are necessarily gendered (I have seen examples of all of the following across genders), but used to better specify between the dyad and the individual in the writing. Where possible throughout the chapter, the singular pronoun 'they' is used instead.

Excerpt 2

```
A: I'm thinking maybe this way rather than that way thaway just seems
   longer tuh me (0.3)
B: oh yea:
A: um I dunno this way might actually be longer ((traces path with
   finger))
```

Hedging the introduction of the suggestion allows both participants to treat it as a suggestion without a strong initial commitment, which may serve an important social purpose for planning: The first idea may not always be the best one, but there needs to be a 'starting point' for the planning. From the launch point of a first suggestion, improvements can be made, details can be established, or alternatives can be presented. The speakers' orientations to this are shown in the way they do not display strong commitment in initial suggesting, at least not before an agreement within the dyad is established. Commitment appears to be progressive throughout the planning process, and once a "best" suggestion is agreed upon by both parties, what was once a mere suggestion evolves into a "plan".

It may also be worth noting that this suggestion is often launched without a separate preliminary statement, such as commonly shown in question-asking [92]. It appears that as both partners are oriented to the task of navigation, they do not begin with preliminaries such as, "Can I make a suggestion?", suggesting that they understand the task as one in which both parties initially claim equal rights to do so. However, this may be an artifact of the research design, in which participants are gathered for the explicit purpose of participating in the study, no one is pre-selected as a leader, and category memberships that may be relevant to asymmetrical rights to action are less pertinent. It is also difficult to claim evidence for a practice through its absence rather than its observable existence. Later in the chapter, I discuss leadership during navigation, during which participants visibly claim and cede leadership more than during planning.

Next, in making the suggestion itself, the speaker takes an extended turn composed of multiple turn construction units (TCUs) to present the suggestion. Speaker 1 claims as many TCUs as required to complete a full suggestion, constructing a multiple TCU turn on the fly. Each TCU by Speaker 1 continues the previous one, while Speaker 2 orients to this ongoing production by providing continuers such as "mm hm" or "yeah". This appears to be inherent in the structure of a navigational route, which necessarily continues from the origin to the destination, but the act of formulating a complete wayfinding plan as a multiple TCU turn needs to be jointly continued by both speakers.

Two examples are shown in the excerpted transcripts. First, in Excerpt 1 above, speaker B silently nods (line 2) as speaker A is making the first suggestion, supporting speaker A's act of presenting an option as well as displaying her comprehension of the suggested route. Second, in Excerpt 3 below, speaker B says "yeah" (or "nnye:ah", line 2) to do the same.

Excerpt 3 Full excerpt in Appendix C.1.

```
01 A: so: maybe we could go like up here, [and take]
02 B:                                     [nnye:ah ]
03 A: like a footpath (.) instead of walking all the way around
04 B: yea:h- but I also feel like what IS this in [the middle]
05 A:                                             [yeah^ I   ] have no idea
06 B: so I'm like WHAT is that (0.5)
```

In line 4, speaker B expands the sequence merely for clarification, "what IS this in the middle?" which continues in line 6. The rest of this excerpt (see Appendix C.1) displays a number of expansions in the original FPP of the base sequence, rising from uncertainty about the correspondence between the map and the environment in the task.

This multiple TCU turn involved in proposing a plan requires both parties to recognize the ongoing nature of the action – in this case, completing the description of a route plan – and participate in it together. In the case of the "nnye:ah" in line 2, speaker B provides an equivocal response to serve as a continuer without explicitly accepting or rejecting the ongoing plan description (as Jefferson describes in her account of the use of these "lax tokens" [93]). This orientation towards speaker A's continuation by speaker B recognizes that rather than producing a suggestion for a segment or part of the route, speaker A is laying out a suggestion for a full route plan to be considered by the dyad.

5.1.3 Responses to Route Suggestions

Acceptance of Suggestion In the second pair part (SPP), the second speaker produces a response to the suggestion proposed in the first-pair part. The simplest way, and the most unelaborated, is an acceptance of the suggestion. The form of the response suggests that it could be the 'preferred' response in this type of suggestion sequence, in that this type of response follows with little or no latency and is not typically hedged.

There are two alternative methods of accepting the suggestion, shown in the following two examples. In the first, Excerpt 1 shows an unequivocal acceptance with "yeah" (line 5; refer back to Excerpt 1 above). This is a basic form of acceptance of the suggestion, where speaker B responds in the affirmative in the SPP before expanding the response to clarify her understanding with "what's this though". This displays clear progressivity to the next action. However, this follows only after speaker A prompts her for a response by asking "right?" and gives her a justification for the route suggestion: "that's sp- what's gonna be (.) straightforward" (line 4).

Excerpt 4 below contains another example of an accepted response, wherein speaker B accepts without providing a clear yes or no response, but by rehearsing the route as suggested (lines 10-14).

Excerpt 4 Full excerpt in Appendix C.1.

```
07 A: UM we can always like just go alo:ng this road here (.) swee::twater
```

```
08    way and then once we see coolbrook we can make a left
09 B: mmhm
10 A: that would be the easiest way
11 B: right at the [round]about, right, right-
12    ((traces path with finger))
13 A:             [yeah ]
14 B: -right, and then coolbrook left
15 A: yeah
```

In cases such as this, the first suggested idea may not be further questioned and is simply accepted. I speculate this is because both parties agree upon it as the same ‘best candidate’ idea held by both, or that the first speaker has sufficiently convinced the second that it is so. Either way, an acceptance aligns both speakers to the same route, adopting the suggestion into a plan or the beginnings of a shared plan.

Presenting an Alternative Suggestion In several instances, an alternative suggestion is presented in response to a first. In these cases, the presentation of an alternative occurs in the second pair-part, and can be done either with or without directly raising an issue with the suggestion first posed in the FPP. This may be the structural equivalent of a disagreement with an assessment – an already-identified dispreferred response to an assessment – and so it is often made less directly than an acceptance or an agreement. However, this does not mean the alternative presented needs to be a rejection of or a disagreement with the first suggestion. Presenting an alternative may take more conversational ‘work’ than simply accepting the first presented idea, but is necessary in cases where the first presented idea is not jointly accepted as the best possible plan. Both parties, if invested in their joint success, need to feel confident that they have exhausted all reasonable alternatives in their planning.

Excerpt 5 gives a representative example of presenting an alternative suggestion.

Excerpt 5 Full excerpt in Appendix C.1.

```
01 A: so mmm the safest way would be to go over around through [here]
02 B:                                                          [yeah] °true°
03    (1.2) or we could ↑also do this like this way
```

In line 2, speaker B appears to have immediately accepted the suggestion by speaker A in line 1 with "yeah true" (partially in overlap with speaker A), but following a pause, returns with "or we could also do this like this way" outlining a new suggestion. Alternatives are often presented with this structure: First, the speaker acknowledges the suggestion, then prefaces the alternative in the form of "or" and "how about" (or again a hedged "what if we") and presents the new suggestion. In this way the second speaker not only validates the content of the suggestion itself, but also the speaker's act of suggesting, which furthers the project at hand.

In a collaborative practice such as planning, it is crucial that both parties contribute to the project by actively making and assessing suggestions. By speaker B hedging the introduction of the alternative suggestion, she presents an alternative as if it were 'equally acceptable,' offering it without rejecting the first suggestion. By not merely settling on the first suggestion, the dyad expands the range of route alternatives to jointly consider in the planning process and subsequent navigation. Beyond the planning phase, dyads who have multiple alternatives available to them assess the various routes in comparison to one another – such as referring to a particular navigational route as "the easy way" or the one that is more "straightforward." By considering a greater number of routes, dyads better prepare themselves for encountering challenges during navigation.

5.2 Challenges in Route Planning and Navigation

The in-depth assessment of video recordings from the planning and navigation activities allows me to look at common wayfinding challenges faced by dyads. Participants in both studies (strangers and friends) orient themselves to recurring considerations during navigational route planning and the subsequent enactment of the route. I select four common challenges and considerations to expand upon here: (1) prospective concerns about accurately remembering the route plan; (2) dealing with the difficulties of map correspondence; (3) flexibly adapting the route during navigation; and (4) jointly bookmarking spatial locations in response to uncertainty.

5.2.1 Memory Concerns during Navigational Route Planning

Memory is centrally involved in route planning for navigation, as a well-laid plan is only as useful as it is remembered by those involved. In this case, remembering the plan is relevant as dyads do not have access to the map or to any physical representation of their route plan (such as in the form of written directions) during the subsequent navigation phase. Even in early stages of planning, people consider the ease of remembering their (route) plan when they are formulating it. Not only that, but people explicitly design route plans that aid memory when later navigating in the real-world environment.

People have many strategies available to them to design a route that is easier to remember. Dyads align to the task of remembering the way during both planning and navigation by discussing and addressing (to differing success) the memory concerns that they preemptively anticipate during route planning. I find several recurring types of responses across dyads to deal with these memory concerns: planning routes that are easier to remember; simplifying individual and shared mental representations of the route plan; and subdividing the task of remembering the route between the two dyad members. All of these responses reflect concerns about remembering and deal with these concerns through simplification.

An example of planning a simpler route by is shown by a dyad who, during planning, expressed this justification directly. One of the dyad members begins, "I feel like for us specifically..." and pauses while their partner traces a route with their finger that follows the main road around to the destination. The plan they discussed was the most common across all dyads in Studies 1 and 2, and is shown as Plan A on Figure 3.2. The first speaker confirms by responding: "yeah just taking the road," showing that they agree on the 'simpler' plan. Immediately following this the speaker states, "I'unno (if) I trust us enough to just cut like straight through." Here they allude to their shared ability to remember and carry out an alternate road which uses the footpaths rather than the longer way around staying on the main (perimeter) road. Many dyads in this way decided upon what they believed to be an "easier to remember" route amongst multiple options, perhaps to purposefully preempt potential issues of memory.

Use of Mnemonic Devices

Some dyads employed mnemonic devices to simplify their mental representations of the route plan. A mnemonic device is a mental shortcut to facilitate the memorization of some information, most commonly in this context a list of street names. The primary use of mnemonics across the collected videos was to remember only the sequential order in which different streets appeared in the dyad's route plan (and not metric information). In the examples collected throughout this set of studies, a mnemonic device was used in a very bare-bones fashion, where most participants only encoded the order of streets in this way, e.g. "S, C, S" for Sweetwater Way, Cool Brook Lane, and Silkberry Lane. This use of mnemonics simplified the street names along the route to their initials only – which was not especially reliable when several street names shared the same initial.

Interestingly, participants did not verbally include the associated turn directions (such as left or right) with this type of mnemonic use, suggesting that they either encoded the series of turns separately (e.g. right, left, left), remembered the overall shape of the route, or that the street-name mnemonic was under-specified. The more common strategy for encoding the route, as expressed by more of the dyads across both studies, was to remember each of the required turns along the route as pairs of cues and associated behaviors or actions, such as left or right at the intersection with the first street, left or right on the second, and so on. This relates to the work by Denis et al. [11], which found that people communicate routes in their basic form by linking sequential planned behaviors, such as making a turn, with cues or specifiers in the environment. The use of mnemonics in the collected examples appeared too coarse, unless mnemonic devices were used in conjunction to the series of turns or a mental encoding of the overall shape of the path.

In any case, this type of route rehearsal would suggest that the participants were relying more on an egocentric route-based strategy, rather than a strategy based on encoding the overall shape of the environment or the direction of the destination from the origin. This is appropriate for the task, which takes place within a neighborhood that has a complex layout rather than a regular (orthogonal) street grid. By examining the planning dialogues in this manner, we can see that participants deal with concerns about remembering the route plan by reducing or simplifying the available information. In some cases, they may over-simplify the route during encoding. However, in the subsequent navigational phase, this may not allow them to flexibly adapt their wayfinding en route or deal with the challenges of becoming misoriented. Indeed, many of those who remembered key streets only by their first initial struggled en route to recall their names (such as remembering only that a street "started with a 'C'").

Related to mnemonic use, others did not go so far as to simplify streets to their initial letters only, but instead used parts of street names (e.g. "Cool-Sweet" as a simplification of "Coolbrook and Sweetwater"). In some cases, this caused issues of incorrectly transposing parts of street names, such as changing "Sweetwater" and "Silkberry" into "Sweetberry", which made recall during navigation difficult. Indeed, several participants mentioned to their partners that they were hoping merely to recognize the relevant streets ("I'll know it when I see it") rather than being able to recall their names precisely.

Divide and Conquer

Another method of simplification exploits the advantage of the dyad itself to distribute the burden of memory across both members. Dyads in some cases used what I call a "divide and conquer" strategy to remember the route, in which one member was responsible for one part of the route plan, and the other member was responsible for the other part. This is clearly shown to be problematic in many of the collected cases. When neither partner has independent access to the full route or environment representation to work with, there is no room for error or flexibility in adjusting the route plan.

One example from a stranger dyad in Study 1 demonstrates a poor outcome with the use of the divide and conquer strategy. The dyad's attempt to work collaboratively during navigation was handicapped by a 'divide and conquer' strategy for memorizing their route and by studying only the streets relevant to their plan. During planning, they focused exclusively on two street names that cued important turns on their route. When they encountered trouble committing both names to memory, they decided each person would focus on only one of the street names. Once in the actual environment, this dyad struggled with correspondence between their plan and those unstudied options. The dyad demonstrated uncertainty throughout the entire task and explicitly stated this in the follow-up questionnaire. One stated, "Most of the navigation I felt lost, at one point I knew for sure we were on the right path, but then [became] confused when I didn't see the way we planned to take." They acknowledged disagreement at several points during the task, which is repeated during their decision-making within the environment as well.

Another dyad, a pair of friends from Study 2, also decides to divide the route between themselves when encountering trouble in rehearsal. This occurs quite late in the planning process, after having already spent over nine minutes deciding on a route and attempting to memorize it. One of the dyad members communicates trouble to her partner by asking her partner "do you remember it?" and admitting "I don't". She then suggests, "I can remember the first part, you can like remember the last part." Although in this case they do not verbally adopt this plan, the suggestion points to uncertainty on the part of the speaker about her ability to remember the complete route plan. This again predates the trouble they encounter during navigation, which includes becoming lost en route and making an incorrect first guess about the destination location.

5.2.2 Difficulties in Map Correspondence

One of the main challenges that arose across both the planning and navigation tasks was performing the correspondence between the provided paper map and the external study environment. Difficulties in such correspondence between the map and environment included the challenges of identifying the objects or locations shown on the map, determining the proper scaling between the map and the experienced environment, and remembering the shape of the environment.

Identity of Landmarks

One central concern with regards to understanding the correspondence between a map (or other symbolic wayfinding aid) and the physical environment is identifying landmarks. This is key to all aspects of understanding the locations within the environment and the relative distances between locations, to allow the navigator to gauge how far they have travelled towards the goal or a sub-goal along the route.

Commonly referenced landmarks within the study area included the traffic circle, which marked the first decision of any route between the given origin and destination locations, the footpaths, the 'open area', specific streets or intersections of streets, and specific houses. The origin location was unambiguous (participants started there and were told it was the origin point), so it was not considered a landmark in these studies. However, participants did have to identify the location of the destination, as there was no indicator marking it within the physical environment. They did so by remembering the location of the destination point on the paper map in reference to surrounding landmarks, such as its location between "the second and third house" (along a street, when approaching from a certain direction) or by its proximity to an intersection.

The traffic circle, the only one within the study area, was easily identified by nearly all participants. Named streets, those intended by travel for motor vehicles, were also easy for participants to identify from their street signs. However, some places along the streets had no nearby signs naming them, or were misinterpreted. In just a few cases, the street signs, which run parallel to the street they are naming, were misread as identifying the street that they are perpendicular to, especially at an intersection.

Identifying the footpaths, which were not named, was more challenging for participants. In the transcription that follows, one friend dyad attempts to match the footpath they are looking for with what they see in the environment as they approach the entrances to the footpaths. This excerpt follows a lull in the conversation before they resume discussion of their next planned turn onto the footpath.

Dyad D23 [1:39 – 1:50]

```
01 B:   and then we were gonna go ((motions slightly to the right))
02      on the footpath remember? you 'member? ((motions forward))
03 A:   well y^eah but there's no FOOTPATH
04 B:   I know that's what I'm sayin' like how-
05      how are you gonna KNOW w^hen it is?
06 A:   is it this ^one? [this is a footpath   ] ((points right))
```

```
07 B:                   [I think it’s this one] yeah ((points right))
08 A:   this is a footpath
09 B:   yeah (.) ay is it? >yeah yeah yeah yeah yeah<
10      ((points forward towards footpath)) ’cuz we were gonna go-
11      (0.8)
12 A:   oh yeah like this ((points ahead)) *and then that*
13 B:   hh.hh.hh until we went around remember? w- was ^it?
14      ((motions slightly to the left in semicircular motion))
```

Not seeing anything that corresponds yet to what they would recognize as a footpath (lines 3-5), speaker B asks how they will be able to “know when it is” (line 5). This simultaneously suggests the footpath is further from the last turn than they may have expected (in terms of distance) and coordinates their attention to the active search for the entrance to the footpath. Once they identify the sidewalk leading into the footpath area as a candidate for the footpath entrance, they each identify the footpath nearly in overlapping talk. Speaker A first points to the right and asks “is it this one?” (line 6) as their partner quickly follows with a point and a hedged confirmation, “I think it’s this one.” Speaker B asserts this more strongly in line 9 as they move closer and gain visibility of the entrance.

The above example not only demonstrates the challenges of identifying specific landmarks, based both on a prior concept of what something like a “footpath” may look like and primed through anticipation of where such a landmark should occur along their progress within the environment. By drawing their joint attention to the task of identifying the landmark, this dyad accurately achieves this slightly ahead of where they can fully view the footpath and is able to do so without slowing down or pausing their forward progress.

Scale of Environment

In terms of scale, commonly observed challenges were identifying the lengths of various segments of the route, such as the elapsed walking distance along a street before anticipating the footpath entrance. These segment lengths or distances were important for participants to estimate while following their plan because it allowed them to question whether they may have overshot the location of their intended next action (such as turning onto another street or pathway). Participants, either explicitly or implicitly, had to work to calibrate the map scale to the scale of the environment. This was important to establish from the very beginning of the situated navigation.

In one example, a friend dyad noted the scale of the environment from the very beginning of their navigation. For all dyads the first decision point was at the roundabout (a relatively clear landmark), so the distance from the origin point to the roundabout was the first useful indication of scale. Shortly after beginning to walk down the first street and identifying the traffic circle, visible from their location, one dyad member notes to his partner, "thought it should be like a lot bigger," and after his partner agrees, he adds "yeah I can clearly see the roundabout."

In at least one other case, dyads even discussed the anticipated *width* of the footpath versus the actual width of the footpath as experienced in the real-world environment. See this next example from a friend dyad:

Dyad D21 [2:11 – 2:23]

```
01 A:   is that the s^econd one? (0.1)
02 B:   I don't know:... (0.2)
03 A:   I think so
04      (1.6)
05 B:   yeah I think so ((points forward towards footpath))
06      (1.1)
07 A:   I think I was expecting the street to be much l^arger (0.2)
08 B:   yeah me too
```

```
09      (2.0)
10      I guess that's why it's a footpath
```

In line 1 above, speaker A is referring to the second entrance of the footpath that the dyad is searching for and has identified a candidate for it. However, they express this in a manner that seeks confirmation from their partner, but speaker B only responds with uncertainty: "I don't know..." (line 2). Shortly after, in line 7, speaker A returns with an explanation for their uncertainty: "I was expecting the street to be much larger." This can be understood to refer to the width and not the length by speaker B's response in line 10, "I guess that's why it's a footpath," as opposed to its being labelled on the paper map as a street.

Shape of Route and Environment

The shape of the route as well as the shape of the study environment were important considerations in dyad communication. In particular, for those dyads who incorporated the footpaths as a central part of their route plan, recognizing the shape of their route along the paths was critical to their wayfinding success. As there was no signage from the turns off of the footpath – either on the footpaths themselves or at the intersections of the footpaths to the main streets – proper turns from the footpaths in order to follow dyads' planned routes were only discernable through the shape of the path travelled so far, or the facing direction within the environment.

In this following example, one stranger dyad deals with the trouble of having exited onto a street early from the footpath; namely, taken an unplanned turn off of the footpath onto a cul-de-sac before the planned turn off of the footpath. After recognizing that they are not where they intended to be following their last (incorrect) turn, the dyad is able to use the shape of their planned route to help troubleshoot their previous turn.

Figure 5.1: Partner A gestures in Line 10. Top center frame shows camera view of the researcher following the dyad; bottom-left frame shows chest-mounted camera view of Partner A; bottom-right frame shows chest-mounted camera view of Partner B.

Dyad C28 [8:03 – 8:17]

```
01 A:   let's think about this logically, oka^y ((stops walking))
02 B:   (stops walking and turns body partially towards partner)
03 A:   cause [you saw the ma-      ] ((raises hands with palms up))
04 B:         [I feel like it would-]
05 A:   okay you saw the map, right? ((rotates hands to parallel))
06 B:   it seemed like we were supposed to be longer on the foot[path]
07 A:                                                           [yeah]
08 B:   it didn't seem like that was like- ((rotates hands slightly))
09 A:   and the left we were supposed to be ((points ahead))
10      taking here ((makes a wide circle motion while pointing))
11      should have been sha^rper, should have been a sharper turn
12      ((raises both hands and makes small rotation with one hand))
13 B:   exactly
14 A:   yeah (0.4)
15 B:   so I think we should have gone longer on the footpath?
16 A:   maybe yeah
```

Upon recognizing that they are not where they expected to be, the dyad attempts to manage their navigational trouble. This takes place not immediately after their incorrect turn, but after identifying several problems: with their current location in relation to where they should be according to the route plan, with the shape of their already-travelled route, and most recently with hitting a dead end. The dyad members clearly reference shape several times throughout their navigation, notably discussed by partner A in lines 9-12. Line 10, pictured in the video screenshot in Figure 5.1, uses a very visible gesture to indicate part of the route. They use both speech and gesture to communicate the difference between their incorrectly travelled route and the planned route. Although use of shape is not universally referenced by all participants or dyads, it appears to be a useful guide for those who are able to use it as a cue.

5.2.3 Route Flexibility during Navigation

Evidence from the route planning process in these studies also demonstrated that some participants explicitly planned their routes with flexibility to account for the uncertainty in the novel environment. By planning for flexible navigation, they were able to adapt en route to change their plan as needed. During planning, the researcher asked the participants to work together to plan a route between the given origin and destination points shown on the map, but did not instruct them to plan alternate routes or back-up plans. (At the start of the situated navigation phase, however, participants were explicitly told they were free to change their route or plan during navigation.)

In one instance, a friend dyad demonstrated that having many plans available to them allowed them to successfully shortcut to the destination. During planning, they considered and discussed multiple route options due to uncertainty about whether their primary plan would be possible in the real environment, as it hinged upon being able to cut through an unmarked area on the map. This excerpt from their planning takes place after an initial few minutes of discussion and selecting a plan.[4]

Dyad D40 [2:02 – 2:46]

```
01 B:   is that the plan? (0.4)
02 A:   yeah but- I'm looking at these two and since they're shaped
03      weird if they don't actually connect we could cut through there
04 B:   yeah, we could but (0.9)
05      well... okay, so: (0.6)
06      we'll (.) do that (.) if tha^t doesn't work then we go here and
07      if THA^T doesn't work we'll also go around (.) this way (0.1)
08 A:   this one SHOULD work though, cause
09 B:   yeah, that's a lotta room
10 A:   it's probably... entrance way to this little like, pathwa^y
11 B:   mm-m (0.2)
12 A:   so the [pathway meets off right there]
13 B:          [yeah, but it doesn't show    ] a path though
14      (1.3)
15      I feel like it [would    ]
16 A:                  [well yeah] cause it's like a transition area
17      (1.1)
18 B:   hmm: (0.7)
19 A:   well, ((leans back)) have you ever be^en to... **REMOVED**?
20 B:   ((looks up at partner and nods))
21 A:   you know in the back,
22      how's there's like that bike path? ((makes circle with finger))
23      it leads into the nei^ghborhoods?
24      ((points back with flat hand several times))
25 B:   yeah
26 A:   but it's not actually bike PATH
27 B:   OH:: like [try to get through?]
28 A:             [it's just like an  ] a^lleyway, kind of
29      ((pinches two fingers together and makes pulling motions))
30 B:   OH okay, okay yeah
31 A:   so that's what I think tho^se are ((taps point on map))
```

In this excerpt, which begins after the dyad finishes describing a complete route plan, speaker B begins after several hesitations to reformulate their plan as one with several

[4] One place name reference is removed from line 19 for potential privacy concerns.

viable alternatives (lines 4–7). After some back and forth, speaker B again displays hesitation in line 13: "it doesn't show a path though." Recognizing her partner's uncertainty, speaker A further justifies why she believes that the plan "*should* work" (line 8) despite being uncertain on the map by providing an example in lines 19–26. Opening with a reference to a place personally known to both of them (the place name removed in line 19), she draws parallels between the unofficial "bike path" there with what she believes may have a connecting footpath in the novel environment.

5.2.4 Spatial 'Bookmarking' during Situated Navigation

Another phenomenon I illustrate is the act of spatial bookmarking during situated navigation by dyad members. This is achieved by setting one or more reference points, or waypoints, which allow the dyad to communicatively and perhaps physically return to those points at a later time (when no longer located there). Although the technical definition of waypoint as used with global positioning systems often limits the term's use to a physical location marked in a coordinate reference system, I extend the meaning in this context. I define this use of "waypoint" not to mean those locations marked by recording GPS coordinates, but noted for social or individual use by the wayfinders in this study.

Spatial bookmarking, as I introduce here, occurs especially when uncertainty is high at that decision point in the navigation, and the participants return to or reference the waypoint when their previous decision at that location is identified as the possible source of navigational problems. This appears to be primarily an individual act of marking a waypoint that may be returned to in one's own memory. However, it is sometimes secondarily accompanied by a communicative act, giving indication to one's partner to jointly 'place' a spatial bookmark at that location. This allows the dyad to orient to the same reference bookmark later on in the navigation, as needed.[5] I use a few examples from both the first and second studies to illustrate this and give a basic sense of the structure of this phenomenon.

Even in the case of wayfinding strangers, dyad members have established common ground during planning that allows them to be vague in their spatial language when referencing these locations. Participants regularly used vague references to refer to a specific place, alternative choice at a decision point, or the intended path. For example, members of both stranger and friend dyads used ambiguous language quite often: “I feel like it was the other one back there” or urging the dyad to return to the “other place.”

At the first visit to the waypoint, participants rarely verbalized the particular significance of remembering its location. However, they grant a significance to the location, marking it as a waypoint through their mutual orientation towards the location. They commonly achieve this by referencing its role in the route plan or discussing potential uncertainty around the location’s role in the dyad’s route. The following excerpt is from an exchange where a dyad member, seeing that they are unable to reach an agreement at an intersection (potential exit from the footpath), decides for the two of them that they will “peek out and see what’s up over there.”

From Dyad D29 [8:29 – 9:01] Full excerpt in Appendix C.2.

```
A:   I think it’s like somewhere he^re ((circles outstretched arm))
     (1.2)
     cause [it was like in between houses   ]
B:         [hey how bout we peek out and see] what’s up over there
     ((turns and walks through exit))
A:   ((follows partner))
```

[5] The concept of a ‘Schelling point’ or ‘focal point’ from behavioral economics [94] partially relates to a spatial bookmark, in that it describes a shared focal point between people that is likely to be mutually selected (in the absence of direct communication) due to its higher salience for both parties. In this way, a spatial bookmark could also be thought of as a spatial focal point.

This exit, discussed at length by the dyad before partner B cuts their assessment short in lines 29–30, is made relevant shortly after this interaction takes place. After making an incorrect attempt a few minutes later, the dyad decides to go back to "the other place," suggesting a return to the bookmarked location and continuing on the footpath there. Such a vague reference to the waypoint has shared meaning for the dyad, and they are able to return to the bookmarked location directly. Spatial bookmarking in this sense allows the dyad to note locations with personally-relevant and mutually-shared meaning. These bookmarks are not always referenced again later, but become important in cases like the above, where they mark places of prior wayfinding trouble.

5.3 Leadership in Planning and Navigation

Leadership can be dynamic, often changing hands throughout a social scenario. This is especially true for ad-hoc social groupings (or "focused encounters" [95]) that come together explicitly for a task purpose, such as this one. I take the perspective of leadership as a mutual influence process that is shaped by social interaction and varies across contexts [96]. Shifts in leadership can happen both in the short term of the present activity, such as in a task-related situation, and over the long term, such as in the orientation towards an existing dyadic relationship. In this section, I address how leadership is managed socially by dyads during wayfinding. I understand that these shifts in leadership during wayfinding speak to social role-taking as a dynamic process, continually established and reconstructed by its participants.

In Chapter 3, I suggested that initial assessments of leadership by dyad members' self-report showed an orientation towards a collaborative distribution of work during planning and navigation. Only in 12 of 30 stranger dyads (40% of cases) did members report that one person took overall leadership during the navigation, and in no cases did one person claim to lead without their partner separately reporting the same. This is at least partially attributable to the fact that these dyads were strangers previous to their participation together in the study, and therefore had very minimal prior familiarity with one another. Ratios of navigationally-relevant talk also revealed that members of pairs with no reported leader contributed more equal amounts to the navigational discussion (as compared to dyads who reported a leader).

This is further supported in Chapter 4, where I showed that dyads comprising friends reported overall leadership more often (in 21 of 30 dyads, or 70% of cases) during navigation than dyads comprising relative strangers. Additionally, members in friend pairs were more likely to report overall leadership in the dyad (self-report their leadership in the dyad) even when their partner did not separately report that their partner led. It is likely, then, that prior social knowledge and expectations played an important role in the perception of leadership among friends. However, friend dyads also appear to default to collaborative role-taking in this wayfinding task.

Role-taking in these studies mainly falls along two dimensions: strong social collaboration and a leader-follower dynamic. As in Reilly et al.'s classification of social roles [20], these are those who work collaboratively as a dyad versus those who work as leader and follower. Unlike in their classification scheme, however, there are no cases of dyads conducting wayfinding independently, as participants were asked to work together on planning and navigating. I additionally find that displays of competence are linked with changes in leadership throughout these encounters and give examples of those shifts. This assessment of how participants claim and grant leadership follows the model of social identity work in constructing leader-follower relationships by DeRue and Ashford [96]. In what they call the *Leadership Identity Construction Process*, leader identity can be initially claimed or granted prior to any initial claim, and subsequently claimed or granted by a person in response to others' claiming behavior in a process that is "iterative and generative" (p. 632).

5.3.1 Collaborative Role-Taking in Wayfinding

Throughout both the wayfinding with strangers and with friends, I find cases in which both members of the dyad share responsibility for spatial decision-making evenly. These are cases in which there is no identifiable and stable (non-shifting) leader throughout the planning and navigation. It appears to be more common for stranger dyads to collaborate on decision-making than friend dyads, who more often had a discernible leader-follower dynamic with regards to wayfinding.

A highly collaborative wayfinding dynamic did not necessarily ensure success or failure for a dyad. In some cases, the lack of a confident navigational leader caused problems that appear to have stemmed from the dyad's inability to reach consensus in their wayfinding decisions. For instance, one dyad with members who had similar sense of direction and personality scores encountered much trouble throughout the task, not only with remembering the route plan but also in managing their en route decision making. Though one of the members of the dyad reported afterward that they felt their partner had been leading, neither displayed strong leadership during navigation. The ratio of talk between the two members was close to equal over the entire navigation (0.86[6]), and from the coded video recordings, it appears that neither person took a predominant lead throughout.

In this dyad's decision making, each member attempted to establish common ground with their partner to reach consensus before proceeding. The following excerpt portion demonstrates, however, that this often proved difficult:

From Dyad C06 [03:06 – 04:24] Full excerpt in Appendix C.3.1.

[6] In this ratio, 1.0 represents equal durations of talk by each person and 0.5 represents one member talking twice as much as their partner.

```
01 B: we were supposed to make a le-
02 A: LEFT, huh? a LE^FT? [wait (.) THA^T way?]
03 B:                     [that's why I said through the-] through the-
04    that's why I SAID I was like, through the THI^NG (0.1)
05 A: HH.h are you SU^RE?
06 B: NO I dunno^ ((shields eyes, looks in same direction as partner))
07 A: NO we go... ((turns, brings hands together)) kay on the map it was...
```

Only three minutes in, the dyad is already off course from their original plan and disoriented. Revisiting what went wrong (line 1), B suggests they should have gone left instead of right to find the footpath. When A questions B further (line 5) with "Are you sure?" her partner backs down with "No, I don't know," and they proceed to review their ongoing navigation from the beginning (line 7). After further review of their plan using the available communicative resources of speech, gesture, and body positioning, B shows impatience with their inability to figure out what went wrong. B interrupts with "All right, let's just see, whatever. We'll just go through the streets," (lines 51–52 in Appendix C.3.1) and begins to walk away. This prompts A to follow along even while asking, "Well, what are the pathways supposed to look like?", something B would have no reason to know any better than she. Much later in their navigation (not included in the excerpt), B attempts to use a stick to draw their plan in the soil; however, this is quickly abandoned as it does not appear to aid in their mutual understanding.

The persistence that dyads demonstrate in their attempts to jointly coordinate their knowledge, such as in the above use of a stick or other examples of using representative gestures or hand 'maps,' shows that participants orient towards a collaborative role-taking where possible. In some cases, collaborative decision making could clearly be very helpful for dyads, or make up for shortcomings that a single navigator may have had if working alone. In the example excerpt below, one dyad member prevents her friend from taking an incorrect turn from a branch of the foot path.

Dyad D26 [3:42 – 4:18]

```
01 B:   okay this is the fi^rst branch: ((motions right)) (0.1)
02      we igno^re the first branch, of the footpath
03      ((gestures downward with flat hand)) (0.1)
04 A:   oh: [>yeah yeah yeah< you're right you're right]
05 B:       [then we keep going to the second one      ] ((motions left))
06 A:   >yeah yeah yeah<
07 B:   'kay (0.6) we're fi:ne
08 A:   oh go^d *not* good at complicated things (0.6)
09      this is all a test of it, we'll fuck up right he:re too ((points))
10      ((walks onto right branch at the same time partner goes left))
11            ((stops short)) [((runs to the left))            ]
12 B:   it's fi^ne, we're fi- [((looks at partner going right))]
13      hh.hh.hh.hh.WE IGNO^RE THE FIRST BRA^NCH ((motions right))
14 A:   OHH:::
15 B:   dumb... hh.hh.hh.hh (0.2)
16 A:   I^ thought- o^ka::y (0.7) go^od thing hh.HH (0.9)
17      I definitely would've g^one the other way ((points right))
18 B:   it's like turning ri^ght ((motions right))
19      we have to keep going le^ft ((motions left))
20 A:   *oh god...*
21 B:   oh gosh:
```

The excerpt opens with Speaker B anticipating the upcoming turn (line 1). Interestingly, the dyad seems to reach a common understanding of the next turn immediately preceding A's mistake, with exaggerated agreement by speaker A in lines 4 and 6. However, she may be hinting at her own uncertainty in line 9 when she says "we'll fuck up right here too," referring to the exact fork in the trail where she then makes the mistake. Only the mutual noticing of partner A taking the other branch on the trail exposes this mistake, causing A to stop short and run over to her partner to catch up (line 11). Despite having prepared and reviewed the route plan together, speaker A admits in line 17 that she "definitely would have gone the other way" – presumably meaning if she had been travelling alone.

Dyad members often worked together to seek confirmation from their partners at decision points and discuss disagreements that arose, although friends were more willing to disagree outright. Dyad members also commonly helped each other remember parts of the route plan, regularly reciting upcoming turns aloud to make them accountable to their partners. It appears that conversation which anticipates upcoming turns, as seen above, serves this purpose. These presented openings – through anticipations, hesitations, or requests for confirmation – give both dyad members opportunities to align their understanding of the route.

5.3.2 Leadership and Shifts in Leadership

Although many friend dyads and some stranger dyads reported that one of the dyad members primarily lead during the wayfinding task, the role of "leader" over the duration of the planning and navigation is often up for dispute. The default for such a task may indeed be to work collaboratively, as evidenced above. Rather than a fixed role, social leadership more commonly shifts throughout the interaction, especially following navigational trouble. Whereas a competent leader is typically secure in their leadership when things are moving smoothly, claims to leadership can be readily revoked with evidence of wayfinding problems.

Leadership is sometimes claimed outright without necessarily being granted by one's partner. An embodied instance of this is shown in Figure 5.2. Pictured is a friend dyad in which one member walks noticeably ahead of the other, leaving their partner to follow or risk being abandoned. This is one of the stronger displays of physical leading in the corpus because the partner walks ahead of their partner nearly the entire time, to different extents (sometimes only slightly ahead, sometimes several strides ahead as seen below). It is much more common for dyad members to walk together for the majority of the task. This physical show of leadership is not called into question by the partner, but may relate to their prior friendship or knowledge about one another's spatial abilities.

Figure 5.2: Dyad in which one member (Partner B) walks visibly ahead of their partner (A).

Very few cases are so clearly visible as this.

In most cases with a leader-follower dynamic, there are ongoing opportunities for role changes. These shifts in leadership typically occur after a dyad member who is leading demonstrates a lack of competence, such as by failing to remember the route correctly or making an incorrect decision en route. Tolerance that dyad members have for poor leadership does clearly vary, as these shifts can result from a single incident or a series of mistakes. In some cases, one member cedes leadership to their partner after demonstrating several accountable instances of not remembering or misremembering turns on their plan. By displaying loss of competence as a navigational leader, the role of leader can become contested by the follower or even abandoned by the leader themselves.

In other cases, an uneven relationship between dyad members emerges where one member self-selects into a follower role without their partner claiming leadership. This leads to situations in which the leader is selected by default due to a passive partner.

In this next example, one member of a stranger dyad attempts to involve his partner in the discussion of a potential exit from the footpath. The discussion at this point follows unsuccessful prior attempts to collaboratively make decisions. Speaker A takes several turns at talk, pausing to leave space (transition relevant places) for his partner to respond, but her response is relevantly absent.

Dyad C17 [5:19 – 5:32]

```
01 A:   or how far is it ((lifts bottle up)) (0.4)
02      like how far is this walkway remember? ((points ahead on path)) (0.5)
03      is it like deeper in or can we go this way? ((points))
04      (1.6)
05      an- you wanna check this real quick and see what this street name is?
```

Speaker A leaves significant pause three times (lines 1, 2, and 4) before independently deciding in line 5 that they will take the exit to confirm whether or not it is correct (in this case, it is not). It appears here that speaker B avoids taking her turn where one or more is allocated to her. The relevant absence of self-selection by speaker B to take a turn is read by speaker A as either a rejection of being involved in the collaborative decision or high uncertainty about the proposed action, and so he takes the lead and decides for both of them.

Overall, there is great diversity in situations that lead to shifts in the leader-follower dynamic for wayfinding dyads. However, all of these can be framed as either granting or claiming leadership on the basis of relevant competence. Displays of competence here can be subtle, but are usually linked to the ability to make and accurately carry out good wayfinding decisions. Prior social familiarity in the case of friend dyads in Study 2 is likely to have impacted initial beliefs about who is a generally competent navigational leader, but there is not enough background context to know how much impact this familiarity may have actually had.

5.4 Summary and Conclusions

This chapter contributes an extended account of dyadic planning and navigation, examining pairs of strangers as well as friends during a wayfinding task. This is guided by Conversation Analytic methods, which allow me to observe systematicity in communicative structures and turn allocation (including for gestures, e.g. Goodwin [81]). This is useful in order to observe the mutual orientation and shared understanding between conversational partners, some or all of which is built over the duration of the study participation [76].

The assessment of dyadic route planning sequences within this collection demonstrates the social tendency towards agreement, and how it shapes the structure of planning conversation. In some cases, early consensus could undermine the thorough consideration of all possible routing options. Participants mostly do not outright reject a suggested route plan but instead present alternative suggestions, showing that they orient towards their mutual selection of the best possible route to ensure their navigational success.

The most common overarching strategies during route planning for navigating a novel environment appear to be flexible planning, which involves making plans that explicitly consider adapting the route to the physical environment once *in situ*, and planning for simplicity, in order to ensure that dyad remembers are able to remember the route once in the physical environment. In both cases, I find examples of participants accounting for the anticipated uncertainty they expect to encounter once in the new environment.

Dyads show that they deliberately plan with route simplicity in mind, such as by justifying a plan to themselves and/or partner as "easier to remember." This reduces the cognitive load for remembering and enacting the route within the environment. The route plans described in this way have fewer actions, meaning fewer cues and decision points to remember, and show greater adherence to the main roads over the smaller footpaths (although sacrificing efficiency and directness). Wiener et al. [97] described this planning strategy as the *least-decision-load strategy*, wherein people reduce complexity of the planned route by selecting a route with fewer possible movement decisions (pg. 486).

Reducing the overall number and complexity of decisions required to follow a route is likely to make a difference in performance for the task in the present set of studies, which have a fairly high memory load. As participants do not have access to the map as an aid during navigation, they have to therefore encode all relevant information from the map for later recall. Reducing the overall number and complexity of decisions required to follow a route is likely to have led to the differences in navigational performance in the present set of studies, as reported in the Chapters 3 and 4. As participants did not have access to the map as an aid during navigation, they therefore had to encode all relevant information from the map for later recall. Because of this, selecting a simple route which followed well-marked segments (named streets) was the best predictor of dyadic success. As well as by using strategies for selecting simpler routes, dyads also worked to further simplify the planned route for encoding in memory. However, they did run the risk of over-simplifying the plan and contributing to later en route challenges. For instance, use of mnemonic devices often resulted in dyads forgetting the abbreviated route names, especially within an environment where names were often perceived to be 'generic' or 'all sound the same.'

Once arriving within the novel environment, dyads encountered a number of common navigational challenges. These main issues center around the challenges of wayfinding in a novel environment. Participants had to remember the route they had planned, which related both to concerns about individual and dyadic memory as well as dealing with the correspondence between map and environment, such as encoding and recognizing the relevant features of their route. They also had to plan flexibly to adapt to unforeseen challenges, and did so by considering multiple routes or back-up plans. I discuss spatial bookmarking as way to frame the way in which dyads systematically mark important waypoints throughout their navigation. This allows them to establish joint reference points to which they can return when encountering navigational trouble.

Collaborative role-taking during wayfinding did not always mean that communication between partners went smoothly. Both dyads with a highly collaborative dynamic and those with a leader-follower dynamic encountered interpersonal and communicative trouble during planning and navigation. Reaching consensus or mutual understanding sometimes required many persistent attempts at both verbal and gestural communication. Where speech and gesture alone failed, dyad members went to such lengths as using resources in the physical environment to coordinate their mental representations, such as by using a finger or other tool (such as a stick) to draw and reference the route together.

Although dyads mainly worked collaboratively, a notable proportion of dyads did take on leader and follower social roles. Leadership was not fixed but shifted throughout the task. I explore the act of claiming as well as losing or ceding leadership in the wayfinding context. Changes in navigational leadership emerge from visible displays of competence, with failed displays of competence risking loss of leadership. As expected, strangers were more likely to act in collaborative social roles while wayfinding, or at least attempt to do so, suggesting friends are likely to have a prior social basis for establishing leadership, and especially navigational leadership.

5.5 Permissions and Attributions

Section 5.1 partially reproduces work that was previously presented as a COSIT 2019 workshop paper entitled "Suggestion Sequences during Route Planning" [98] in the session *Speaking of Location 2019: Communicating about Space* in Regensburg, Germany on September 10, 2019. Proceedings from the workshop are available at `http://ceur-ws.`

Chapter 6

Comparisons with Individual Wayfinders

In this chapter, I assess individuals performing the same wayfinding task as dyads performed in the first two studies, but without the dyadic interaction. This solo wayfinding performance serves as a comparison to dyadic performance, to better outline the contributions of the social aspects of wayfinding. The main difference in this study is that it involves individuals participating alone in route planning and navigation, rather than with another person (whether stranger or friend). This solo navigation serves as comparison to better allow me to highlight the benefits or challenges introduced by collaboration with a partner. I also evaluate the use of a think-aloud protocol in this individual participant condition to elicit monologues about planning and navigation, and how well that compares to conversational dialogues between dyads in the first two studies.

6.1 Introduction

The main questions of interest in this study are whether individuals' wayfinding performance differs from that of dyads on a comparable planning and navigation task, and if so, which individual difference factors and interactive strategies may contribute to that performance difference. A secondary question considers the value of a think-aloud protocol for understanding decision-making processes during wayfinding. Individuals do not generally verbalize their thought processes during navigation the way that members of dyads and groups necessarily do to communicate amongst themselves, especially when asked to work together on the task.

Several notable lines of research employ the analysis of a think-aloud protocol in similar wayfinding contexts, such as for informing architectural or urban design processes. Passini [99] prominently used think-aloud in a set of architectural wayfinding studies, describing in detail the methodology for having participants verbalize their decision making in multi-level indoor and urban outdoor spaces. People were asked to verbalize their thoughts while finding their way between a few pairs of locations. The transcriptions of these verbalizations were then coded and presented in decision diagrams, describing both the structures and the sequences in each person's verbal decision making. Raubal [100] also explored peoples' verbal descriptions by interviewing them about their imagined wayfinding while looking at photos of sequential locations in an airport, a complex indoor space, connecting the analysis of these verbal descriptions to spatial image schemata.

The exploration of the think-aloud protocol in this study has implications for understanding the extent to which aspects of spatial decision making are consciously available to people and can be verbalized. By examining the verbal content of individuals' think-aloud protocol, I hope to be able to extract the core elements of the process and compare it to navigational decision making between dyads. Broadly speaking, this has implications for understanding how individuals' cognition as a sole wayfinder differs from the social cognition of a dyad performing the same wayfinding task in the same situation.

6.2 Research Questions

To compare dyads to individuals on the aspects of wayfinding I explore in this dissertation project, I pose the following questions:

1. How similar are the routes planned by individuals and dyads? Do individuals appear to consider more or fewer alternative routes in their planning, and what are the possible explanations for this?
2. How does navigational performance appear to differ between individuals and dyads? If so, what accounts for the differences in navigational success?
3. How does the assessment of a think-aloud (or talk aloud) protocol for individuals compare to the assessment of conversational interaction for dyads?

6.3 Method

To facilitate comparison with the results from Studies 1 and 2, I preserve much of the study protocol from the first two studies in this comparison with individual wayfinders. There are again two phases of the study: (1) prospective planning of a route between given origin and destination points, taking place in the lab; and (2) situated navigation of the route in the real-world environment. Refer back to Chapters 3 and 4 for details on the study protocol used for dyads. Only the aspects of the methodology that differ from the previous two studies are described in detail here. See Appendix D for full study protocol and forms.

6.3.1 Participants

Following data collection for the first two studies, 30 individual participants were recruited from the department subject pool. None of the participants had participated in the related studies described in the previous chapters. Each person signed up individually, filled out the individual difference measures online, and reported no (or very minimal) familiarity with the study site when asked in the lab. Participants were run from November 2019 to March 2020 by myself and an undergraduate research assistant.

Ages of participants ranged from 18 to 25 and the average was 20.7 years old ($SD =$ 2.1 years). In terms of gender, 17 were female and 13 were male. This is relatively representative of the gender breakdown in our student participant pool, which tends to skew female. When asked in the lab, all 30 participants claimed to be either "very unfamiliar" ($n = 23$), "unfamiliar" ($n = 5$), or "somewhat familiar" ($n = 2$) with the specific study environment. Those who expressed any prior knowledge of the neighborhood or immediate area were further questioned to ensure that their experience in the neighborhood was minimal and unlikely to contribute to their spatial knowledge of the study site. For instance, they were asked whether had actually been inside of the neighborhood or just on a main street bordering the neighborhood, and if they had been inside the neighborhood, whether it was on one occasion or several. None of the participants reported being inside the neighborhood on more than one occasion.

6.3.2 Individual Difference Measures

See Table 6.1 below for a summary of individual differences for the participants in this study. Individual difference measures did not significantly differ between females and males in this study; see results of two-sample t-tests for sex differences. Male participants in this study had a lower average SBSOD score than the female participants, but this difference was non-significant. Measures of sense of direction and personality were also similar to those of participants in the previous studies (see 3.2.3 and 4.2.3); see Table 6.2 below for means of individual differences by study as well as one-way ANOVA results.[1]

Table 6.1: Means on SBSOD and Big Five Inventory for individual participants (n = 30).

Measures	All Members [Range]	Females ($n = 17$)	Males ($n = 13$)	Sex Differences (all $n.s.$)
SBSOD	3.9 [1.1 – 5.7]	4.2	3.5	$t(27.58) = 1.59$, $p = .12$
Extraversion	3.2 [1.5 – 5.0]	3.4	2.9	$t(23.88) = 1.36$, $p = .19$
Agreeableness	3.8 [2.0 – 5.0]	4.0	3.7	$t(23.37) = 1.33$, $p = .20$
Conscientiousness	3.7 [2.2 – 5.0]	3.7	3.7	$t(27.67) = 0.09$, $p = .93$
Neuroticism	2.8 [1.0 – 4.4]	2.8	2.7	$t(27.33) = 0.27$, $p = .79$
Openness	3.5 [2.4 – 4.6]	3.6	3.4	$t(26.75) = 0.71$, $p = .49$

Table 6.2: Comparison of SBSOD and Big Five Inventory across the three studies.

Measures	Study 1 Averages	Study 2 Averages	Study 3 Averages	Differences across Studies
SBSOD	3.9	4.0	3.9	$F(2,87) = 0.16$, $p = .85$
Extraversion	3.3	3.4	3.2	$F(2,87) = 1.10$, $p = .34$
Agreeableness	4.1	3.8	3.8	$F(2,87) = 1.80$, $p = .17$
Conscientiousness	3.6	3.4	3.7	$F(2,87) = 2.34$, $p = .10$
Neuroticism	2.8	3.0	2.8	$F(2,87) = 1.49$, $p = .23$
Openness	3.5	3.4	3.5	$F(2,87) = 0.44$, $p = .65$

[1] All 3 studies $n = 30$ but Study 1 and 2 reports dyad averages whereas Study 3 reports individual averages.

6.3.3 Procedure

The procedure for this study is modeled on the procedures used in the previous studies with dyads (see 3.2.5 for stranger dyads and 4.2.5 for friend dyads). There are some important distinctions between the procedure used in this study with individuals versus the previous two studies with dyads. The most obvious is that participants were recruited to complete their participation alone, rather than with another participant. Rather than video-recording the social interaction during planning and navigation with pairs of participants, the researcher video-recorded individuals each completing the planning and navigation while simultaneously performing a think-aloud protocol.

The verbal directions given for the individual planning, which took place in the lab room, were as follows:

> “Now, you will be working using a paper map to plan a route that you will have to walk in the next part of the study — without the map. While planning I will also ask you to talk out loud about your planning process. Please talk as if you are thinking out loud to yourself and it will be recorded by the video camera. Working with the provided map only, please plan a pedestrian route to take between the marked origin (“O”) and destination (“D”) locations shown on the map [point to each on the map], minimizing as much as possible the distance and time to reach the destination. Make sure you remember your planned route, as you will not be able to use this or any other map when you walk through the environment in the next part of this study. Again, while planning, please talk out loud to yourself about your thinking process. I encourage you to talk during the whole procedure as if you are thinking out loud. You won’t get any verbal response or feedback from me, but please talk constantly at a normal volume until you are finished, at which point you may

let me know you're ready."

Once the individual had completed planning their route, they were asked to draw and describe their route (as in the previous two studies) as well as to verbally answer the following questions:

1. "Did you consider any alternatives to this route?" (If yes: "Please describe and draw those routes on this map as well.")
2. "Are there any parts of the route or map environment that seem uncertain to you?"
3. "Do you think you would plan differently if travelling with a friend or partner? If so, how?"

These questions were asked to elicit some of the same types of discussion as observed in the previous studies, and to have participants consider whether they believed their planning process would be similar if working with a partner instead of individually.

Following the planning phase, the participant was driven to the same study area as in the first two studies. The verbal directions for the individual navigation were:

> "In this part of the study, you will follow your planned route between the origin and destination locations you previously saw on the map. You will wear a small video-camera and will also be video-recorded by the researcher as you navigate through the environment. You are not allowed to use your cell phone or another map to help you navigate, only what you remember and see in the environment. No need to follow the route exactly as planned before, but take the best possible route to reach the destination. Again, please talk aloud about your thinking process while navigating. Speak at a normal volume, not to me, and this will be recorded by the video-camera. You do

> not need to mention every thing that pops into your head, but anything that might be related to the navigation. You will not get any feedback from me, but please continue to talk constantly until you are finished. When you feel that you have reached the destination point, please let me know. You will have 30 minutes to complete this task."

The follow-up questionnaire after the navigation phase ended was also different in that it asked three questions not present in the previous studies: first, "What was your main strategy for remembering your route plan during the navigation in the neighborhood today?" to see whether individuals had insight into the strategies they were using with regard to remembering their plan; and, "Did you have specific cues or landmarks you were looking for during navigation?" to ask which cues were most pertinent to their wayfinding. These additional questions were asked of individuals to get further insight into their navigational strategy, which was less obvious than when dyads were navigating together (and therefore working together through communication). This was intended to further corroborate the results of the think-aloud protocol, and was occasionally referred to during analysis of the think-aloud protocol. The questionnaire also asked, "Not considering how well you found the destination today, how confident are you in your general sense of direction or navigation ability?" This differs from the previous questionnaires which asked the participant to judge one's *partner*'s sense of direction or navigation ability, rather than one's own.

6.4 Results and Discussion

6.4.1 Navigational Performance Comparisons

Of the 30 individual participants in this study, 16 individuals (53%) were considered successful because they reached the destination on the first attempt.[2] The other 14 individuals were not considered successful, although 7 of them did eventually reach and identify the correct destination location on their second or third attempt. Of the other 7 unsuccessful or failed individuals, 4 gave up before making it to the destination, 2 were incorrect on all three attempts, and 1 was stopped because they ran out of time.

This is a much lower success rate than in the previous studies, in which 26 of 30 stranger dyads (87%) and 22 of 30 friend dyads (73%) correctly reached the destination on their first attempt. The "giving up" behavior was also notable. None of the dyads in either of the first two studies gave up without exhausting their three guesses. Examining this pattern, it appears that there are two main reasons for this: dyads are more likely to persist, perhaps due to social pressure of being in pairs rather than alone, and dyads have more plans or ideas available to them in order to make secondary and tertiary attempts to reach the destination. In terms of apparent social pressure, dyad members would sometimes verbally encourage their partner that they should continue. In some cases, dyad members clearly switched from one person's plan to their partner's when an attempt failed, showing the advantages of having multiple available plans (refer back to the discussion on social leadership in Section 5.3). Individuals, on the other hand, may be more quickly discouraged by making an incorrect guess and have fewer back-ups or alternate ideas available to them.

Because of the lower success rate across the individuals in this study, performance in

[2] Again, the "first attempt" is the first place where the participant reported that they had reached the destination, whether correct or incorrect.

terms of total time and distance is also worse than in the dyad studies. Overall time for navigation averaged 12′ 22″ (12 minutes and 22 seconds) with a range of 5′ 50″ to 30′ 00″ and standard deviation of 6′ 26″. Overall navigation distance averaged 0.70 miles, with a range of 0.36 to 1.76 miles and standard deviation of 0.33 miles. There was therefore greater variance in individuals' time and distance performance than in dyads' performance.

Total navigation time and distance were again highly correlated, $r = .97$, $p < .001$. This shows a strong relationship between time and distance during navigation, similarly to strangers ($r = .94$) and to friends ($r = .86$). This difference in correlations across types of groups is significant between individuals and friends ($z = 2.94$, $p < .005$, two-tailed Fisher z-transformation) but not between individuals and strangers ($z = 1.3$, $p = .19$, two-tailed). It is possible that differences in the strength of the relationship between time and distance is due to communication, considering that differences between time and distance can be accounted for by walking speed and time spent paused. Although individuals did perform a think-aloud protocol while navigating, it did not seem to impact their travel efficiency the way communication between friends may have.

Additionally, although not all GPS tracks were accurately recorded for friend and stranger dyads,[3] pausing and slowing behavior as recorded may suggest the same thing with regards to the efficiency cost of social communication during wayfinding. Individuals spent the least amount of their navigation time paused (or walking slowly, under 1.5 miles per hour) as compared to dyads, only pausing on average for 13.1% of their total navigation time, whereas stranger dyads paused for an average of 15.2% and friend dyads for an average of 16.2%. Individuals also had the highest average walking speeds and lowest standard deviation in average speed over their recorded navigation, suggesting

[3]For stranger dyads, 11 GPS tracks were missing or poor quality. For friend dyads, 9 GPS tracks were missing or poor quality. For individuals, just 1 GPS track was missing.

they may have walked faster and been more similar in their average walking speeds than dyads. Prior research shows that there are average walking speeds that are most comfortable or preferred by people, based on factors such as gait and energy expenditure [101], and that individuals walking together do calibrate to their partners' walking speeds in some cases [102]. However, I make the caveat that the differences between the studies for pausing and walking speed are non-significant with the available GPS tracks. It is unclear whether this pattern would emerge with larger samples.

In comparing the difference in total navigation distance and time between the participants in all three of the studies, individuals performed significantly worse than friend dyads, but not better or worse than strangers. See Figure 6.1 for jitterplots of total distance and time measures for all participants across the three studies. In terms of distance, individuals navigated a greater distance than did friends ($t(58)$ = -2.7, $p < .01$), but not significantly more than did strangers. Individuals also navigated for significantly more time than friends ($t(58)$ = -2.3, $p < .05$), but not significantly longer than strangers.

To compare navigational efficiency across all participants in the study, I turn now to the navigational time and distance to the first attempted destination (first guess). These results are plotted above in Figure 6.2. One participant was not included in this analysis because they did not reach at least one location where they believed to be at the destination before running out of time (30 minutes). Individuals' time and distance to the first attempted destination – which was correct for those who succeeded and the first incorrect guess for those who did not – averaged $10' \, 07''$ and 0.58 miles. Comparing across group means, individuals travelled significantly further to reach their first attempted destination than did friends ($t(57)$ = -2.4, $p < .05$) but not further than did strangers ($p = .67$). Individuals also travelled for longer to reach their first attempted destination than did friends ($t(57)$ = -2.3, $p < .05$) but not longer than did strangers ($p = .82$). This generally follows the same pattern across the studies as for *total* time and

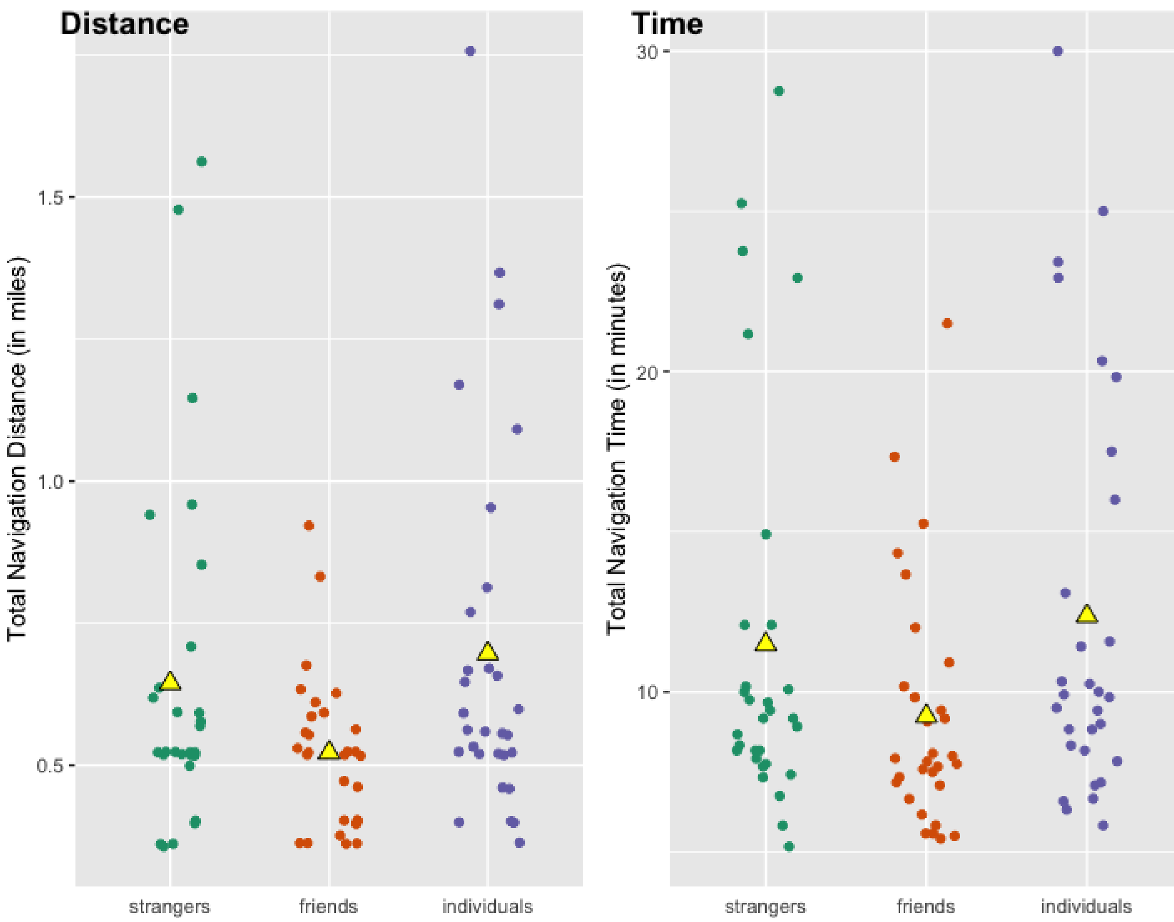

Figure 6.1: Jitterplot of Total Distance and Time across the three studies.

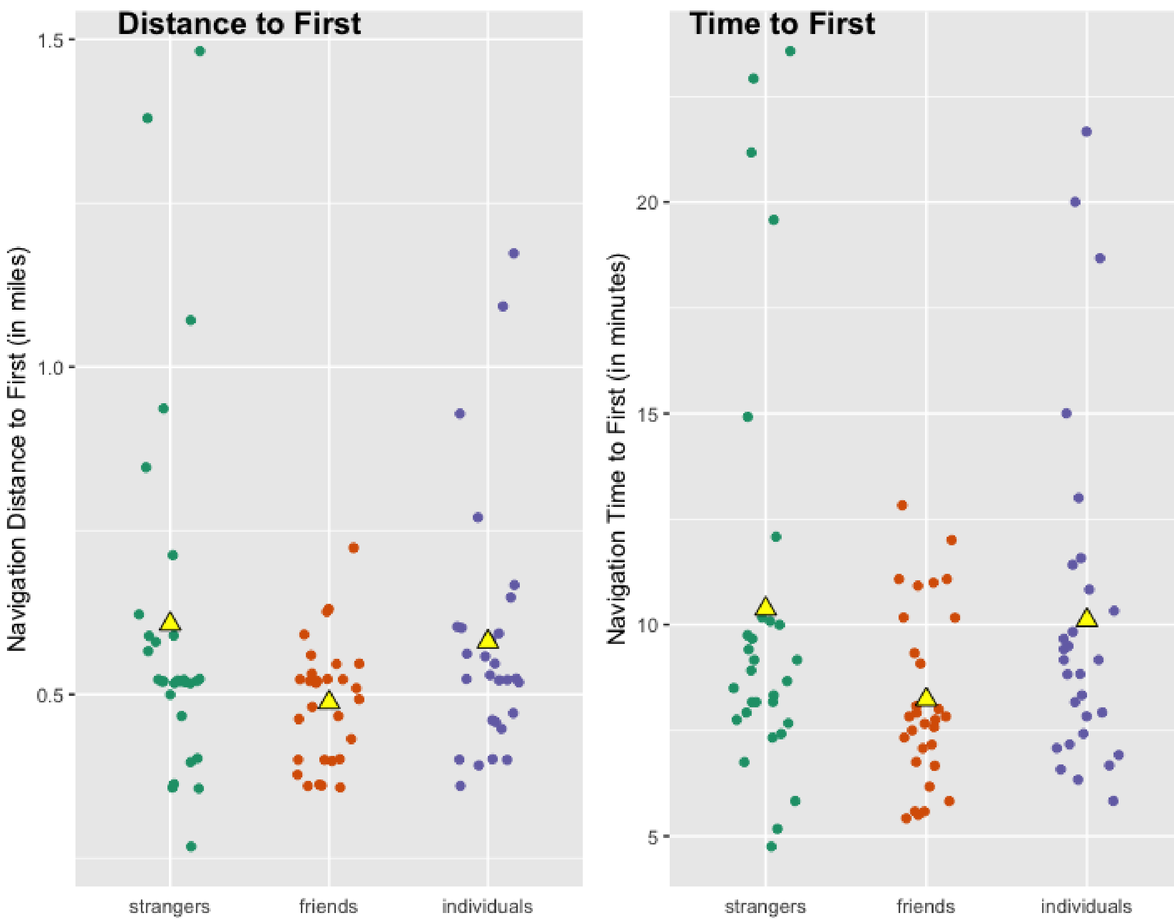

Figure 6.2: Jitterplot of Distance and Time to first attempted destination.

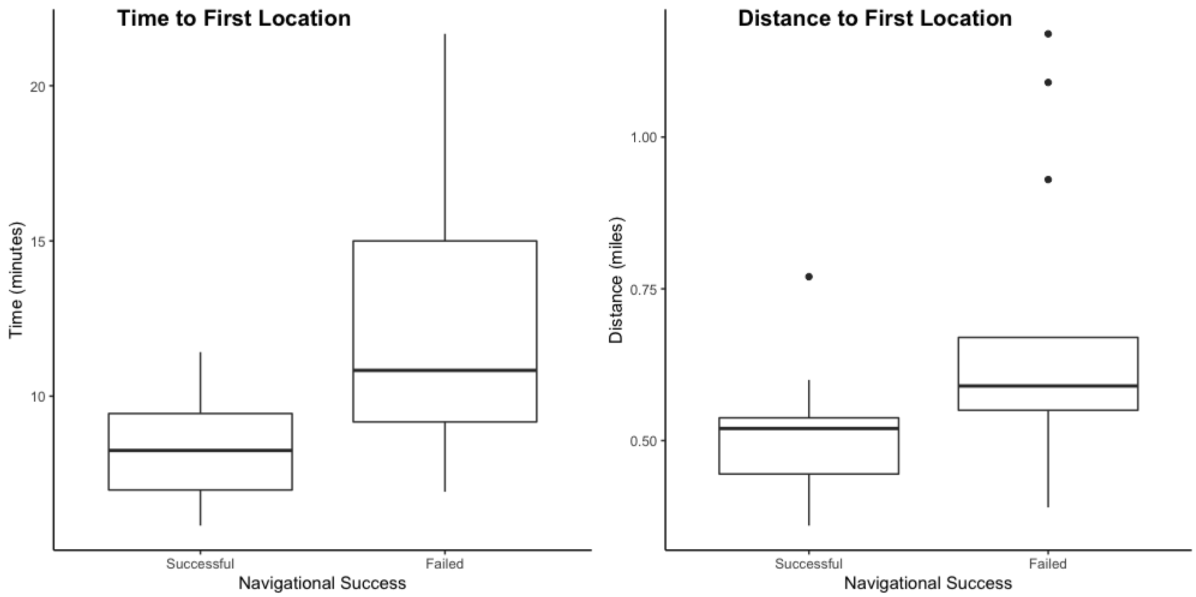

Figure 6.3: Time and distance to first location based on success.

distance reported above.

Looking at navigational success in reaching the destination on the first attempt, those 16 individuals who were ultimately successful averaged less time and distance to the first attempt location than those 14 who were unsuccessful. For time to first location, successful individuals averaged 8′ 16″ and unsuccessful individuals averaged 12′ 23″. This is significantly different between groups, $t(14.01) = -2.88$, $p < 0.05$. For distance to first location, successful individuals averaged 0.51 miles and unsuccessful individuals averaged .67 miles. This group difference is also significantly different, $t(15.23) = -2.31$, $p < 0.05$. See Figure 6.3 below.

Overall, the navigational performance measures show us that fewer individuals were successful than friend dyads, and even fewer were successful than stranger dyads. Individual wayfinders were more similar to pairs of strangers than to pairs of friends in terms of both total time and distance, as well as time and distance to the first attempted location. We saw again that, as appeared to be the case with strangers and with friends, individuals who were ultimately successful in reaching the destination in their first attempt also travelled more efficiently to their first (and only) attempt than did those were unsuccessful on their first attempt.

6.4.2 Individual Differences

I next compare individual participants' navigational performance to their individual difference measures, focusing on sense of direction and personality dimensions. In these results, sense of direction as measured by the Santa Barbara Sense of Direction scale (SBSOD) and personality dimensions as measured by the Big Five Inventory (BFI) only somewhat relate with observed navigational performance, as I report here.

Gender and Sense of Direction

Performance, as measured by overall navigation time or distance, did not significantly vary by participant gender, $t(25.24) = 0.85$, $p = .40$ for time; $t(23.46) = 0.10$, $p = .92$ for distance. Although average SBSOD scores appear to be different for males and females (refer back to Table 6.1), this difference was not significant in this study. The slightly higher SBSOD scores for female participants in this study are perhaps interesting, however, as males averaged higher individual SBSOD scores in both of the previous studies.

It is again worth noting that, in this study as with the previous two studies, better sense of direction does not predict better navigation performance (as might be expected in such a task, depending on how people approach it). Sense of direction was also not significantly correlated with any personality dimensions. Although those individuals with higher SBSOD scores averaged more time and distance to the destination (and first attempted destination), this was non-significant (for SBSOD and time to first attempt,

$r = 0.16$, $p = .41$; for SBSOD and distance to first attempt, $r = 0.17$, $p = .38$). Sense of direction may not necessarily be the best measure of success on such a wayfinding task in this study design, as success on this study task was more dependent upon accurate route following than survey ability (except when taking novel shortcuts). Since participants were allowed to plan any route between the given origin and destination, it is possible that better sense of direction may lead to the selection of more complex routes. This effect could occur through greater wayfinding confidence, leading those who think of themselves as having better navigation abilities to plan more difficult routes to minimize distance, ignoring or discounting the possibility of getting lost.

In a relevant post-navigation survey question, I asked participants to rate their confidence in their *own* general sense of direction or navigation ability on a 4-point scale from "not confident" to "very confident". The first bar graph below in Figure 6.4 plots the count of responses to this question. However, the majority of respondents (20 of 30, or 67%) rated themselves as "confident" and those who rated themselves higher (as "very confident") or lower ("not confident" or "average") did not reliably differ in terms of route plans.

This replaced the question in the previous friend dyads study pertaining to respondents' confidence in their *partner's* directional abilities. In retrospect, it would have been interesting to ask all participants in the previous studies to additionally rate their *own* abilities, to determine whether they thought their spatial abilities were evenly matched with their partners, were superior to their partners, or inferior to their partners. This would have given us further insight into whether leadership in those dyads related to perceived (relative) spatial abilities. It appears that people rate their own navigational abilities about the same as they do their friend partners' navigational abilities, at least when asked in this manner. The second bar graph in Figure 6.4 above shows that friends in a dyad rate their partners in approximately the same way that individuals appear to

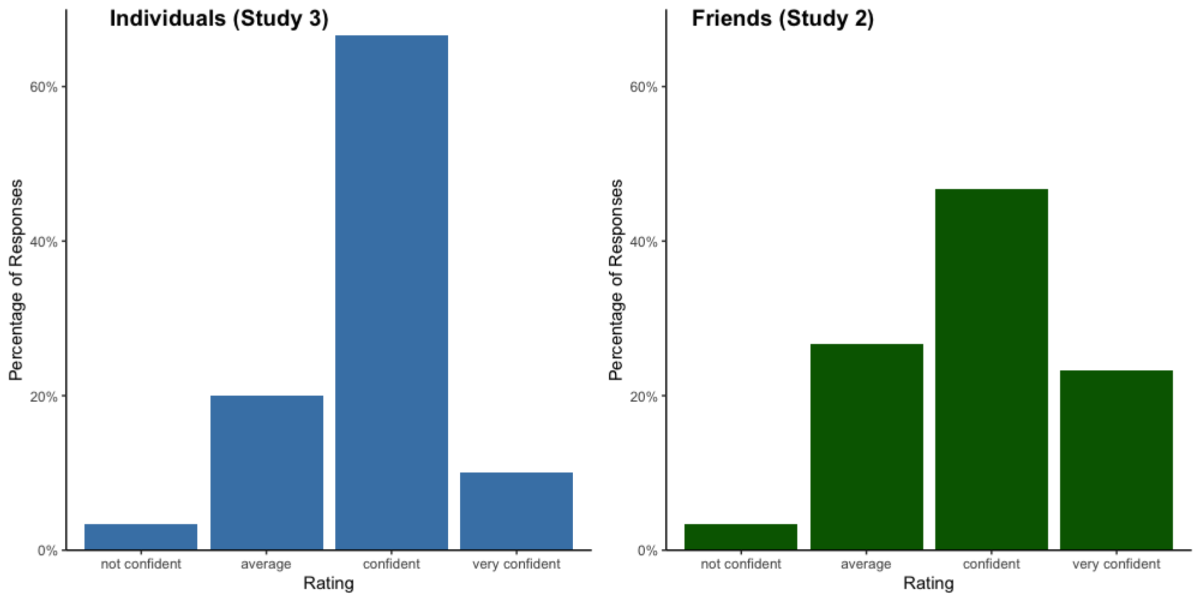

Figure 6.4: Individuals' self-assessment of navigational ability and dyads' assessment of friends' navigational ability.

rate themselves.

Personality

Only a couple of personality dimensions appear to stand out in relation to performance: Higher scores on Openness to New Experience correlate to *more* time and distance travelled to the first attempted destination (r = .48, $p < .01$ with time to first; r = .42, $p < .05$ with distance to first); and higher scores on Conscientiousness similarly relate to worse performance (r = .35, p = .066 for time to first; r = .36, p = .054 for distance to first). I interpret these connections with personality to suggest that individuals who have higher Openness to New Experience scores may try more potential shortcuts, leading them astray, or that openness may be predictive of individuals who select more difficult routes in the first place (such as planning a route that takes the footpath). These individuals may be more inclined to try making an unplanned turn to reach the destination faster, even when not part of their original plan. In section 6.4.5 below, I explore this further in relation to individuals' adherence to their route plans.

6.4.3 Individual Route Planning

Time spent by individuals to plan their routes in the lab ranged from $0' \, 40''$ to $10' \, 40''$ with an average planning time of $2' \, 55''$. There are no significant differences between planning time in this study and in the previous two studies; see Figure 6.5 below. It is interesting to note that one person plans for the same amount of time as two people, who must coordinate and agree upon a plan. As with the results for route planning from the previous two dyad studies, planning time was not associated with success (as measured by proportion who reached the destination on their first attempt, or any of the time or distance performance measures). Only 9 unique route plans were reported by individuals, comparable to the 9 plans for stranger dyads, but fewer than the 16 different plans reported for friend dyads. This shows more variation in planning by friend dyads than in route planning by either individuals or stranger dyads.

However, after reporting their primary route plan, individuals were further asked whether they considered any alternative routes during their planning and the majority clearly did. This question was inspired by the unprompted discussion of contingency ('alternate' or 'back-up') route plans by friend dyads in Study 2. In 90% of cases (27 of 30 individuals), participants reported at least one alternative to the reported route plan when asked. Although some provided descriptions of up to four or more alternate routes considered, participants were not prompted to explain more than one alternative route in response to this question. This shows that in nearly all cases, people chose their route plan over others and were unlikely to have just selected the first viable route they saw between the origin and destination points. Only 3 individuals reported not considering any alternative routes.

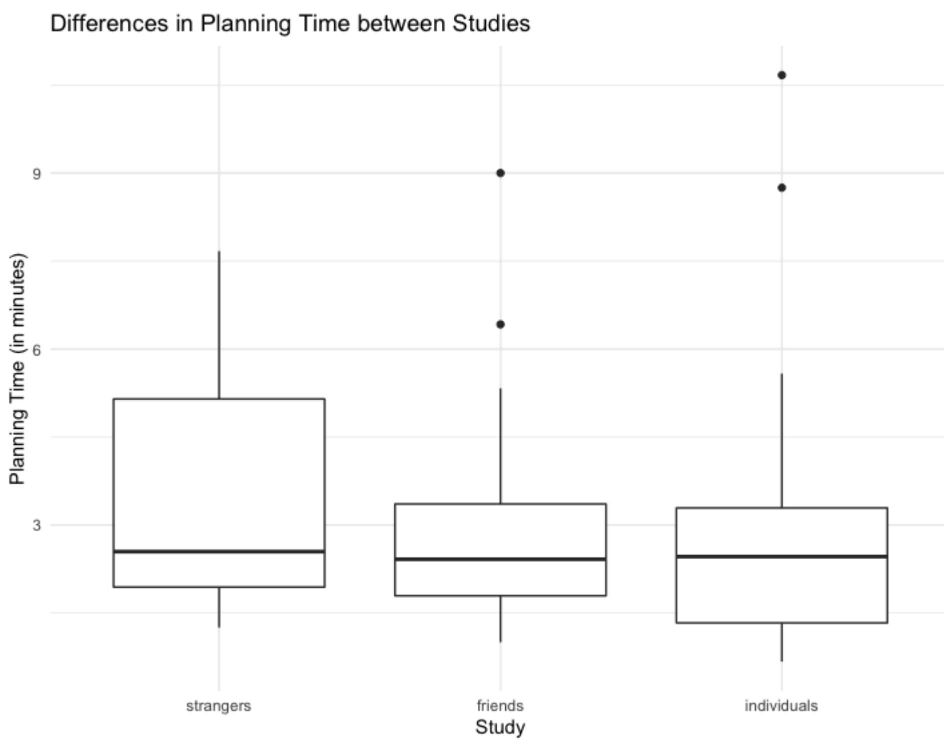

Figure 6.5: Differences in planning time across all 3 studies.

The most popular routes reported by individuals were also the “safest” routes. In this study, 13 of 30 individuals chose and reported the on-road route as their primary plan (Route B; see Figure 6.6 below). For reference, this was the longer route that circumvented the central area, avoided taking any footpaths, and only used marked streets. This is similar to what was previously reported by stranger dyads (as described in Chapter 3), where 12 of 30 dyads chose the on-road route, and more than the number of friend dyads (6 of 30) that reported this route. In fact, of those 17 participants who did not report Route B as their primary route, 10 of them reported Route B as their alternate or back-up plan in case their route did not work out as planned.

One primary barrier to selecting a route that took a footpath through the middle area appeared to be uncertainty about what was present in the ‘middle area’. In reality, this middle area (refer back to Figure 3.1) is a vernal pool, which is a seasonally occurring pond or lake area that appears in times of high and/or sustained precipitation. In the map, this area was only represented as a minimally shaded region with cross-hatching. It is crossed by a number of foot paths, which were labelled on the provided map. There was high agreement between solo participants that this area was a source of uncertainty for them. In response to a post-planning question about whether there were any uncertain parts of the map, route, or environment, 17 of 30 people (57%) mentioned the middle area. They referred to this area by a variety of terms: the “middle area” (12 mentions), “this” (1), the “river” (1), the “lake” (1), the “whole field” (1), and the “water or the forest” (1). The overwhelming majority of these responses specifically expressed uncertainty about the *identity* of this area (i.e. uncertainty about “what the middle area is”), and in fewer cases about whether individuals would be able to cross this area on foot. Therefore, the uncertainty around this area is likely to have been a factor that dissuaded some participants from planning a route that depended on crossing the region using the footpaths.

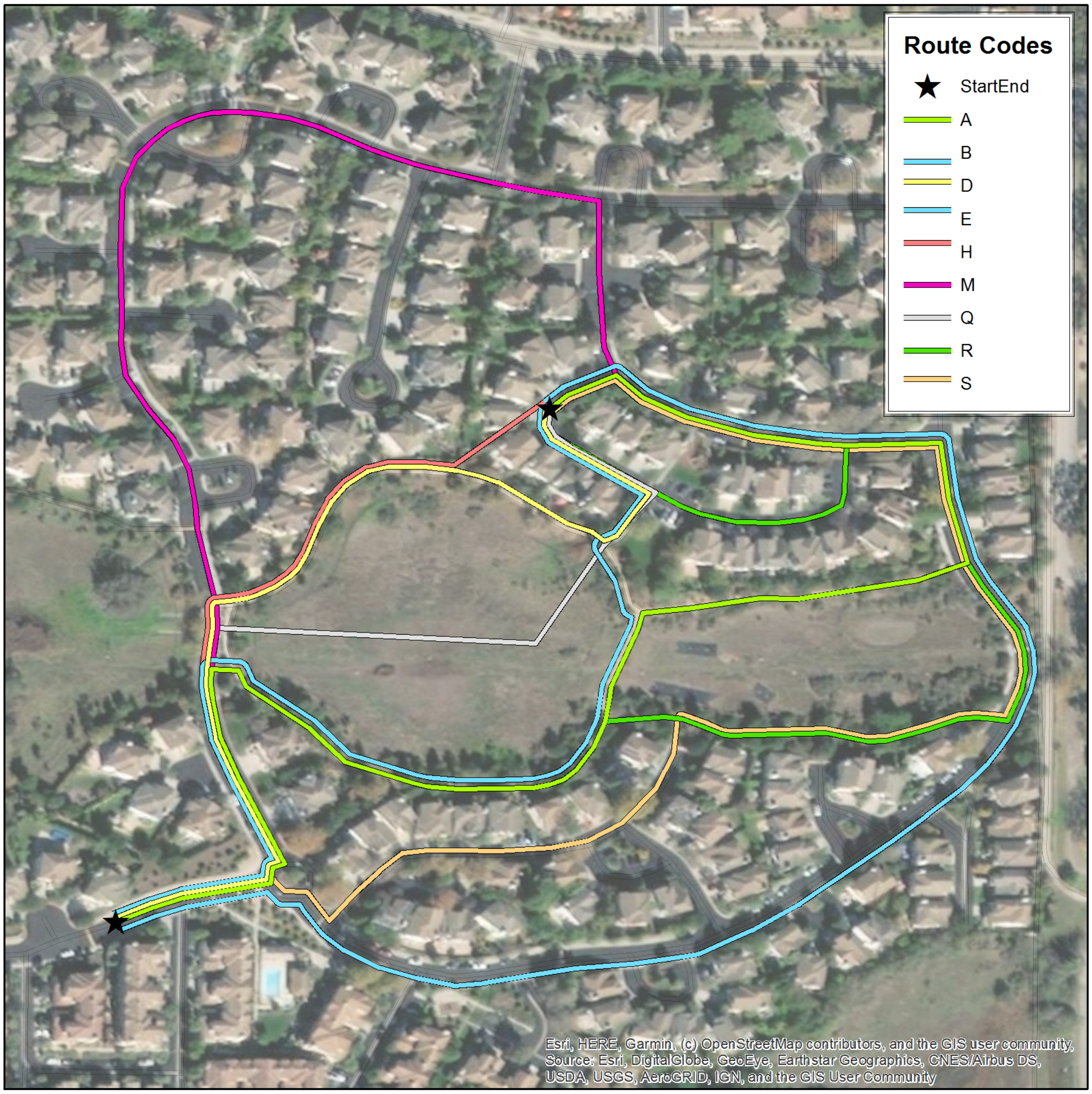

Figure 6.6: Map of unique route plans reported in Study 3 by individual participants.

Participants were also asked after planning and describing their routes whether they thought they would have planned any differently if they were working with a friend or partner. Although this question was added mostly for exploratory reasons, it was interesting to examine these responses. More than half of the individuals (16 of 30, or 53%) said they would *not* have planned differently if they were working as a dyad, but the remaining 14 (47%) did speculate that they would. Those 14 individuals gave various explanations: as a pair, participants thought they may be safer or more courageous (or opposingly, that they may want to choose a "safer" or more populated route), might have better memory of the route (or opposingly, that they may need to choose an easier route to remember), might choose a more aesthetic route, or might discuss more options with their partner and choose more collaboratively. In some of these cases, different people gave completely opposing reasons for why they believed they would travel differently with a partner, highlighting the complexity of social interaction in navigation. This also highlights the inherent unreliability of self-report with regard to imagined scenarios, and the need for more systematic explorations of solo versus group wayfinding.

6.4.4 Comparison of Route Plans across the Three Studies

The top five routes planned across all three studies is shown in Figure 6.7, rank-ordered A through E for the most popular (Route A) through the fifth most popular (Route E) based on the total number of dyads or individuals who reported each of the routes. In Table 6.3, I report the ranked popularity of each of these five plans, the count of participants (dyads or individuals) who reported each of these plans for Study 1, Study 2, and Study 3, and the total count of participants who reported each of these plans across all three studies. These top 5 route plans are the same 5 most popular route plans chosen by participants for Study 1 and for Study 2, but Routes D and E were not as popular for Study 3 participants; other routes, not shown here, ranked higher for Study 3 participants.

Figure 6.7: Five most popular route plans across all 3 studies. (Same as Figure 3.2.)

To characterize the relative complexity of each of the plans, I report in Table 6.4 various indicators of route complexity for each of these top 5 overall routes. These indicators include distance, total number of turns on the route, and the number and proportion of

Table 6.3: Top 5 most popular route plans, by study.

Route Code	**Ranked Popularity**	**Study 1**	**Study 2**	**Study 3**	**Total Count**
A	1st	12	6	13	31
B	2nd	7	5	6	18
C	=3rd	4	5	3	12
D	=3rd	7	4	1	12
E	5th	4	5	0	9

Table 6.4: Route complexity measures for top 5 route plans.

Route Code	**Ranked Popularity**	**Distance (mi)**	**Total Turns**	**Unmarked Turns (Proportion)**
A	1st	0.52	3	0 (0%)
B	2nd	0.56	6	3 (50%)
C	=3rd	0.27	4	1 (25%)
D	=3rd	0.36	4	3 (75%)
E	5th	0.57	6	3 (50%)

turns that are unmarked (no visible street sign at or near the turn). Distance and fewest turns have commonly been reported as the most important indicators in peoples' route selection criteria (for instance see Golledge [103]). This table again includes ranked popularity to show how the complexity of a route may relate to the popularity of choosing certain routes. As I previously noted in the analysis of conversational interaction, the distance of the route (actual or perceived) was not the sole concern for decision-making, despite participants being asked to minimize both time and distance. If it were the case that participants had full confidence in remembering and carrying out their selected routes, the shortest distance route should also be the one which takes the least travel time. But the fact that the shortest routes were not the most popular suggests that participants recognized their uncertainty about successfully carrying out the route during situated navigation.

This table supports the prior claim that the most popular route, Route A (shown in blue in Figure 6.7), is indeed the least complex: It only includes three turns, with all turns marked with the relevant street sign in the environment, making them recognizable entirely by their street names. Out of all the plans reported across the studies, Route A would have the lowest cognitive load and therefore be easiest to remember for participants. However, Route A does not have the shortest length of all possible (nor popular) routes, meaning that participants likely considered the greater simplicity of the route to be a worthwhile trade-off for travelling a greater distance – and perhaps for longer. The cognitive complexity of a route is likely to also be affected by other features, such as a route's shape and the types of turns involved. For instance, the angle of a turn or number of choices available at each turn may contribute to the complexity of remembering and carrying out a route. Future research along this line of work should systematically vary the types of turns involved amongst several routes to better elicit the relative contributions of a route's features to a route's complexity.

6.4.5 Adherence to Planned Routes

Similarly to the dyads in the previous studies, individuals travelled faster to their first attempted destination when following their planned route more closely. As before, I calculated both the distance ratio and the route overlap as measures of participants' adherence to their route plans.

Distance Ratio

The distance ratio is reported as the distance of the enacted route divided by the distance of the planned route.[4] Therefore, any distance ratio above 1.0 means the participant travelled further than planned. For individuals in this study, the distance ratio ranged from 0.64 to 5.07. Three participants travelled a shorter distance than their reported plan (distance ratio below 1.0). Most individuals (19 of 30) travelled farther than

[4] *Distance Ratio = Distance of Enacted Route / Distance of Planned Route*

intended, and the maximum distance ratio of 5.07 shows that one person walked more than 5 times the distance of their route plan. The 30 individuals in this study had an average distance ratio of 1.55, as compared to that of friend dyads (1.22) and of stranger dyads (1.34). However, the difference in means across the three studies is non-significant ($F(2,87) = 1.29$, $p = .28$). This means individuals on average travelled further than they had planned (some much further), but it is unclear whether individuals also travelled relatively further than friend or stranger dyads.

Route Overlap

The second measure of correspondence is route overlap, calculated as the distance of the overlapping segments between the planned route and the enacted route divided by the entire distance of the enacted route, for each individual participant.[5] Route overlap for individuals averaged 65.3%, compared to 75.4% for friend dyads and 69.1% for stranger dyads, but the differences in means between the studies are non-significant ($F(2,87) = 0.79$, $p = .46$). Eight of 30 individual participants (8 of 30) followed their route exactly as planned without even minor deviations from the reported plan; this is lower than the number of friend dyads (16 of 30) or stranger dyads (10 of 30) that did. Thus, it appears that more individuals in this study either got lost or took alternate routes from their primary planned route, as compared to the dyads in the first two studies.

This is corroborated by individuals' responses to the post-navigation question about whether and why they deviated from their planned route. The question asked, "Did you take a path that was different from your planned route in any way? Describe if so." Twelve of the 30 individuals reported following the same route they had planned. Responses to this question were coded as "lost" if the respondent reported being lost, missing a turn, or being unsure of where they were during the navigation; coded as "alternate" if they

[5] *Route Overlap = Distance of Overlapping Segments / Distance of Enacted Route*

said they took another path but indicated they were sure about their route; and coded as "shortcut" if they said they took a novel shorter alternative path to their destination. Of those 18 individuals who did *not* take their originally planned path, 14 of the responses were coded as "lost", 2 as "alternate", and 2 as "shortcut". In summary, participants often took a route that they recognized as a deviation from their original plan (or plans), and in the majority of those cases, the enacted route was said to result from becoming lost while navigating.

The correlations between route overlap and individuals' time and distance to the (first attempted) destination were negatively related, r = -.47, p = .011 for distance, and r = -.60, $p < .001$ for time. Therefore, with more overlap between the planned and enacted route, individuals travelled faster to the first attempted destination. This is the same pattern found for friend dyads and for stranger dyads, as shown in the previous studies. The relationship between adherence to the planned route and efficiency of navigation is consistently supported across the three studies, again highlighting the important role of planning in successfully wayfinding through a novel environment.

6.4.6 Think-Aloud Protocol for Planning and Navigation

For solo wayfinders, I additionally explored the value of using a think-aloud protocol for comparison to the social interactive aspects of the dyadic studies. In think-aloud, participants were asked to verbalize their thought processes while completing a task. This has been used in navigation and wayfinding studies previously, typically to elicit spatial considerations during decision making (e.g. Passini, 1992; Raubal et al., 1997; described in section 6.1 above).

In this study, individuals were asked to perform a think-aloud during both the prospective planning and situated navigation phases. As part of the task instructions for the planning phase, participants were instructed, "While planning I will also ask you to talk out loud about your planning process. Please talk as if you are thinking out loud to yourself and it will be recorded by the video camera." For the navigation phase, participants were asked, "Again, please talk aloud about your thinking process while navigating. Speak at a normal volume, not to me, and this will be recorded by the video-camera. You do not need to mention every thing that pops into your head, but anything that might be related to the navigation. You will not get any feedback from me, but please continue to talk constantly until you are finished." They were asked only to mention what they thought was related to the navigation, rather than asking them to talk continuously throughout the situated navigation.

Participant comfort with the think-aloud, especially during the in-lab planning phase, varied across individuals. Most participants (23 of 30, or 77%) spoke comfortably during the planning phase of the task without further prompting to carry out the think-aloud, but 7 individuals (23%) only spoke out loud minimally or with hesitation. There are a few factors that may have contributed to this discomfort during planning. For one, the researcher was sitting at a nearby table, not directly facing the participant during this task and not responding to the participant's verbalization, but close enough to hear what the participant was saying in real time. Another possibility is that the novelty of the think-aloud may have made it initially awkward to perform.

Initial discomfort about verbalizing during planning seemed to carry over less to the navigation, however. During navigation, a similar proportion of participants (25, or 83%) carried out the think-aloud apparently comfortably, while 4 others spoke minimally and 1 did not speak at all (only gestured). Participants spoke more easily, with no further prompting, during the entirety of the navigation. It appears that the act of walking while talking out loud may have accounted for further comfort with the task during navigation, where cues in the environment often prompted relevant talk. Also, the researcher was walking far enough behind that the participant likely felt they were talking more for the recording than for (or to) the researcher. On average, individuals in the study talked for 16.7% of the time during navigation ($SD = 14.2\%$), ranging from 1.2% to 57.9% across all individuals.

Overall, the think-aloud protocol seemed to be effective for eliciting the main features and cues used by participants, as well as their strategies for implementing their route plan *in situ*. It helps highlight the common topics of focus and allows for comparisons across the individual study and the previous two dyad studies. I describe how these individual think-aloud protocols support the claims made in the previous chapters, especially the propensity for more successful participants to plan and navigate adaptively.

Topics of the Planning Think-Aloud

Common topics discussed by participants during planning mirror many of the topics outlined in the dyadic planning process. These topics related to identifying main map features, route comparison and selection, and then route memorization with some amount of simplification of the plan. This individual process of assessing potential routes has parallels to the dyadic route suggestion sequences (refer back to Section 5.1.1), of course without the benefit of having a second person offer acceptance or present alternative suggestions.

As mentioned above, individuals spoke relatively minimally and appeared to be doing much of the comparison stage of route planning silently. In some cases, individuals only started speaking their thoughts aloud to verbalize a route plan after first looking at the map silently for a period of time. This suggests that it was difficult for individuals to perform the think-aloud protocol while still working on understanding the map and deciding upon a route among open possibilities. This may be due to the lack of further specification in the think-aloud protocol instructions: Participants were not told exactly what to talk about, such as specific features of the map as they noticed them or their impressions of each possible route through the pictured environment.

Topics of the Navigational Think-Aloud

The majority of topics verbalized during navigation were as expected, including: rehearsal of plans, anticipation of upcoming decision points and their associated actions (turns or continuations), and adapting to unexpected circumstances such as changing one's plan en-route. Individual participants rehearsed plans in much the same way as dyadic partners did in communication, by rehearsing the relevant steps as encoded during planning. However, individuals often did so in a more halting fashion, with no conversational partner to help rehearse the plan more fluidly or otherwise fill in the pauses.

In many cases, individuals spoke not only about their thoughts or planning actions, but their navigational behavior as well. It was common for participants to narrate their actions as they were making them; e.g. "I'm making a left onto Coolbrook Lane" or "keep going straight". In the wayfinding context, these are still considered relevant to the think-aloud protocol, as it was overwhelmingly more common to narrate an action prior to taking the action rather than concurrent with it. This echoes findings by Brunyé et al. [104], which show that the process of decision-making begins well before reaching a relevant intersection during wayfinding.

Anticipating Next Turns

Individuals, like dyads, clearly demonstrate that they anticipate their upcoming turns or decisions well before reaching the point at which they become relevant (at intersections). In the case of the individual participants in this study, these statements about the upcoming decision typically followed the prior action – i.e. anticipating the next turn immediately after carrying out the previous turn – or occurred sometime during the approach to the turn, when the individual expected to see a cue for the turn (such as a fork in the path).

Anticipating the upcoming turn may serve various purposes, such as priming oneself for visual search or rehearsing the action to be taken in the scheme of the entire route plan. The think-aloud protocol helps demonstrate that, as with dyads, individuals took aspects of the environment and their own plans into account in the context of situated navigation, including identifying landmarks, gauging the scale of the environment and the relative distances between features, and understanding the shape of both their route and relevant aspects of the map environment. In the following example, one participant considers the distance between the origin point and the roundabout relative to the remembered map.

Individual E20 [0:21 – 0:33]

```
wait I wonder if this is the roundabout tha:t... (0.5)
wai:t the map and this is like
like- completely different
the distance is WAY off
(1.7)
but (.) this is a roundabout so I'm turning right
```

This excerpted transcript from the participant's think-aloud protocol occurs as they approach the roundabout. This one example shows typical commentary recognizing this feature (Line 1), but also demonstrates that the participant considers the scale of the environment with relation to the map seen before (Lines 2–4). Their talk makes it clear that they were not expecting to see this feature so soon into their navigation – note the multiple hesitations and "wait" repeated twice – but recognizes it clearly enough to cue their decision (Line 6). It appears that this anticipation of next turns not only allows wayfinders to search for relevant cues in the environment, but also prompts them to consider how it fits into the ongoing navigation. In addition, this anticipation potentially helps wayfinders understand what it means if they do *not* find the relevant cues where expected (e.g. when they have overshot the turn or made a previous error).

Route Flexibility during Navigation

Considering the fairly high number of individuals who got lost or took alternate routes to their originally planned routes, there was evidence that many adapted their plan or route in response to the real-world environment and its unexpected challenges. The following excerpt is from an individual participant, starting about 2 minutes into the navigation. This individual recognizes that they are possibly not following their route along the footpath as originally planned and adjusts their contingent understanding of the wayfinding in progress.

Individual E04 [1:46 – 3:14]

```
think it's this one right here ((looking ahead to entrance on right))
(14.1) ((turns and crosses street to reach footpath entrance))
awright, I know it was on the r:ight side (0.4)
and second... right ((makes small curve with right hand))
(12.5) ((walks along path))
except this goes aro^und a little bit more than I thought
so maybe it mighta been a little bit slower to come around this wa:y
(1.8)
on the map it looked like it cut across more
(4.9)
but maybe it starts to go across more as, I go farther in
(11.5)
I'm not even sure what the fi^rst
(1.3)
ex^it is gonna look like
(7.8)
and I'm pretty sure this is [going... no^rth                   ]
                            [((makes small curve with flat hand))]
if I remember from the ma^p (0.5)
and I feel like if I went all the way around, I'd still be going::
northeast-ish ((motions with flat hand)) (0.8)
so I feel like I am, cu^tting (0.9)
across a little bit mo^re
```

Figure 6.8: This screenshot shows both the view from the researcher's handheld video camera ("Researcher") and the participant's chest-mounted video camera ("Participant") at timestamp 1:48 (Line 1 of the above transcript).

Figure 6.9: This screenshot is at timestamp 1:58 (Line 2 of the above transcript).

```
24   than I would be if I had just gone around
```

Lines 1-2 demonstrate that the participant anticipates the entrance to the footpath (recognizing it visually; see Figure 6.8) just before making the action to cross the street (Figure 6.9) and enter the footpath. In Line 3, having just completed the previous action of locating and taking the footpath, they plan their next action to take the right branch of the path just before it becomes relevant (reaching the fork in the path). Immediately following this, in line 4, they state their next planned turn as well ("and second right") – much before it becomes relevant.

However, as they continue walking along the footpath, it appears the slight curve in the shape of the path cues the participant to some trouble (Lines 6-7). After a pause, the participant relates this in Line 9 to the correspondence between how the footpath appeared on the map during planning and how it now appears in the environment: "on the map it looked like it cut across more." They deal with this by adjusting their understanding of the ongoing action, both by considering that they have not yet reached the curve "across" (Line 11) and comparing it to a possible known alternative to their main plan (Lines 17-24), again consulting their memory of the map (Line 19). This flexibility in the participant's understanding of their ongoing route is aided by their memory of the shape of the open area and its paths.

Personal Uncertainty and Hesitation

Throughout the navigation phase for individual participants, there was a considerable amount of self-reflection on one's spatial or memory abilities, especially in relation to one's own progress – such as when believing oneself to be possibly lost. There was also much uncertainty about *whether* one was lost, as it was often unclear to participants whether they had gone off-course or were still on track to their destination as planned. Not having a partner or an external navigational aid in these cases seemed to give individuals few resources for dealing with the challenges of disorientation or misremembering.

Individuals frequently hesitated to take risks, and may have had lower thresholds for tolerating uncertainty than dyads. Not only did some individual participants give up entirely on finding their destination (as stated above), but some also decided against attempting potential shortcuts. For instance, one individual who considered shortcutting through the middle area using footpaths during planning decides against it when approaching the possibility during situated navigation:

Individual E33 [0:50 – 1:07]

```
01   oh tha^t's Buttonwood
02   (1.4)
03   I wonder... (0.9)
04   I wonder if I were to make a le^ft there if I'd ge^t there
05   (4.2)
06   I can tr- mm::
07   (2.3)
08   na^h I'll just go around
```

This individual notices the relevant street name and recognizes the opportunity to shortcut through on the footpaths, and appears to be on the verge of deciding to try it (Line 6), but ultimately decides against it and take the streets all the way around instead (Line 8). Although it is not possible to assert that this individual may have been more likely to try this "riskier" route with a partner, a partner may have helped aid this individual's memory of this alternative or their confidence in attempting it.

Use of Gesture

Participants in the individuals study also used gesture commonly during navigation. They were not given any specific instruction as to whether or not to gesture, so any such motions are assumed to be fairly natural or spontaneous rather than produced for the sake of the researcher. Neither were they exclusively produced for the sake of their wayfinding partner, as gestures were produced by participants even when they were out of visible range of their partner.

Gesture commonly co-occurred with speech describing the planned route, paths, or environment itself, mostly happening in overlap with individuals' spoken descriptions. Most gesture use was related to shape of the environment or the planned route, making them *representational gestures* [105]. Specifically, my collection of interactional cases show that these gestures were intended to use shape to represent semantic meaning. It was common to use one's hands (usually a finger, flat hand, or the whole forearm) to 'redraw' the path when attempting to revisit the shape of the route. This appears to indicate that participants used these gestural motions as a direct representation of the route, possibly to aid their memory. These types of shape gestures mostly co-occurred with concentrated periods of time when participants were figuring out why they were lost or off-route.

Looking back at video recordings from the first two studies, it is clear that dyads (like individuals) also gestured to indicate route shape, especially when attempting to establish a common understanding of the route plan. As with individuals, dyads did this independently as a memory aid even when not communicating to one's partner. For instance, there were clear instances in which a dyad member made small hand motions mostly invisible to their partner – and therefore unlikely to be produced as a communicative gesture. However, in the dyad cases it is likely that such representational gestures were used both as an aid to memory *and* for communicating with their partner, such as to establish a common understanding of either the route plan or the route as travelled so far.

Gesture occasionally appeared to replace individual participants' verbalization of their thoughts, even for those who otherwise spoke consistently throughout their navigation. The notable absence or sudden drop-off of talk during the think-aloud protocol suggests that gesture could more readily allow participants to concentrate on remembering the route or mentally working out a problem. For example, one individual who thought aloud almost constantly through the beginning part of their navigation suddenly realizes they are unable to remember the next part of the route (first stating around 9′ 21″ "aw now I get lost"), and then (around 9′ 39″) silently revisits the route with finger gestures similar to tracing a path in the air.

The prevalence of gestures visibly increases after individuals acknowledge that they are (or believe themselves to be) lost. This is true of dyads as well, in that one or both members gesture more upon recognizing their navigational trouble. There were additionally a few isolated examples of individuals or members of dyads switching to a different language (presumably a more familiar or native language) in periods of navigational difficulty. In these cases, speakers who had a primary or native language other than English would switch briefly to their other language.[6] This switching between languages, as with switching between talk and gesture, may relate to ease of accessing spatial representations in memory.

6.5 Summary and Conclusions

In this chapter, I reported navigational performance by individuals working alone using the same procedure as for the stranger and friend dyads. I also compared individual differences within this study and across studies to find that individual differences only relate minimally to navigational performance on this task. The assessment of individuals' behavior and strategy use during planning and navigation helped to elucidate differences in overall performance. By comparing individuals' think-aloud recordings to the conversational interaction by dyads, I draw parallels between the types of actions performed by both individuals and dyads during navigation, as well as outline the added benefits and/or challenges of wayfinding in pairs versus alone.

One of the central questions from this study is whether individual wayfinders are more successful than dyadic wayfinders. On nearly every metric of navigational performance measured in this study, individuals performed more poorly than did dyads (whether strangers or friends). Fewer individuals than dyads successfully reached the destination. Only just over half of the participants in this individual study (16 of 30) reached their

[6]In these studies, those languages included Spanish, Chinese, Korean, and French.

destination on their first attempt, as compared to 73% (22 of 30) friend dyads and 87% (26 of 30) stranger dyads. Four (13%) of the individuals who failed on their first attempt also gave up before making all attempts, suggesting they abandoned hope in being able to find the destination. In fact, forfeiting behavior was not discussed in the previous chapters because it was not observed amongst dyads. Social structure, even at the dyad level, seems to be an important motivator to persevere in the task at hand. This may manifest through increased persistence in the presence of a wayfinding partner or a greater confidence in the dyadic or group-level abilities.

Individuals were less efficient navigators. Overall, individual wayfinders took more time to reach the destination and travelled further to do so. Differences in navigation efficiency were not attributable to differences in sense of direction or personality characteristics, nor did individuals spend more or less time planning than dyads. In terms of applied wayfinding strategies, individuals face more difficulty with the tasks of remembering and have fewer resources available to them during navigation than do dyads. Much of this relates to differences in planning, decision-making, and memory during navigation. Individuals had a smaller pool of reported unique route plans and more often planned 'safer' or simpler but longer routes, hinting at lower confidence about successful navigation. Indeed, I previously showed that dyads were able to consult one another about their decision-making en route and recognize each other's mistakes in time to correct them, which helped them follow their planned routes more accurately. Contrastly, when a solo navigator made a mistake in their progress such as forgetting a turn along the route, there was no one to remind them.

Individuals may have access to fewer collaborative resources than those in dyads and potentially larger groups, who have additional means for remembering and assessing alternatives. There were many complex tasks involved with the situated navigation, including performing the correspondence between the map and the physical environment, rehearsing the route plan and anticipating upcoming decisions, and flexibly adapting one's route. Although individuals certainly expressed their own uncertainty at points throughout navigation, not being socially accountable to a partner during navigation may have led to less questioning of their ongoing progress. This in turn can mean fewer 'checks' on their navigation or challenges to their decision-making, as the solo navigator remains entirely responsible for their own success.

The use of the think-aloud protocol for this comparison of planning and navigation gives additional insight into individuals' planning, reasoning, and decision-making. Individuals mostly showed comfort performing the think-aloud task while being video recorded, more so in the situated navigation context than during the in-lab planning. One caveat is that there was a tendency among some individuals to narrate only their actions rather than their thinking process behind them. I attribute this to the lack of experience or guidance with the think-aloud protocol. Instructions may have been too open ended, and individuals may have benefited from a training period for what they were expected to talk about. Additionally, when dealing with wayfinding problems during navigation, I witness that some individuals temporarily dropped their think-aloud (although continuing to gesture while thinking silently). This may hint at the cognitive load involved with verbalizing one's thought processes.

Alongside spoken language, gesture may provide an additional window into spatial memory and reasoning during wayfinding, as we see in the ways that individual participants used representational gestures in the navigation phase. Previous work has also shown that gesture is used more frequently by people in describing spatial information than when describing non-spatial information [106]. Those researchers found that restricting gesture constrained participants' ability to produce speech related to spatial information. Likewise, here we see that people may find it easier to recall the route or plan their spatial behavior with the use of gesture. Gesture use increased when participants believed themselves to be lost, and in some cases appeared to replace verbalizations. The collected examples suggest people find it easier to 'revisit' the route in their minds by making gestures mimicking a physical revisiting or retracing of the route. More work on individual differences in gesture use in relation to spatial cognition would indeed supplement these findings [105].

Chapter 7

General Discussion

Social wayfinding is a relatively recent area of inquiry in the field of spatial cognition [107, 17, 18]. Spatial cognitive research deals with questions about how people form representations of the physical spaces they inhabit and how people use this knowledge and understanding to shape their behavior, such as moving throughout these spaces. Wayfinding is concerned with how people plan and remember routes from one point to another, as well as how people select routes and maintain orientation during navigation in the environment. Several important and complex processes of cognition are involved in carrying out a wayfinding task, including prospective planning, problem-solving and decision making, and dealing with spatial uncertainty.

However, wayfinding research thus far has largely focused on the individual scale of analysis, with the study of individuals finding their way through an environment alone. The research I present in this dissertation expands our understanding of wayfinding in a real-world situated context, by which I mean both the physical environment as well as the social environment of working with a partner. I conducted a series of three behavioral studies which recruited participants to work either in stranger dyads, in friend dyads, or individually to plan a route through a novel environment and carry it out in the real-world setting. In this final chapter, I summarize the main findings across the three studies and their contributions to the field of spatial cognition and related research in wayfinding. I also discuss shortcomings of this work and open questions for the future of research in social wayfinding.

7.1 Overall Wayfinding Success

There are a number of ways that success in wayfinding can be defined, some of which may be more relevant to this project than others. I primarily defined success as reaching the destination point correctly within the time limit. However, even for those who did so, there was a large range in time and distance travelled to reach the destination, so I additionally use time and distance (navigational efficiency) as an indicator of success. Some participants were additionally able to take novel shortcuts to the destination once in the situated context, even when they had not previously planned to look for a shortcut or attempt to take one.

Some notable differences emerge between the success of stranger dyads, friend dyads, and individuals across the three studies. Of the three social groupings studied, individuals were the least successful in reaching the correct destination location on their initial attempt (first location claimed as destination). Only just over half were able to do so (53%), whereas friend dyads had more success (73%) and stranger dyads even more so (87%). Dyads also demonstrated more persistence even after encountering challenges or incorrect attempts during navigation. This is shown in examples of dyad members who continued to make attempts, often with verbal encouragement by their partners, or worked together to revisit their plans and ongoing progress, whereas some individuals gave up after making one or more incorrect attempts.

For efficiency in terms of time and distance, friend dyads performed significantly better than both stranger dyads and individuals. Friend dyads travelled less total distance than did stranger dyads, but differences in total time between friends and strangers were only marginally significant. Friend dyads were also more efficient to their first attempt than strangers, in terms of both distance and time. Compared to friend dyads, individual participants took more time (both overall and on their first attempt) and travelled further (both overall and on their first attempt), but travel times and distances for individuals did not significantly differ from that of stranger dyads. Therefore, friend dyads were clearly more efficient in navigation than stranger dyads and individuals, but that strangers and individuals were indistinguishable from each other on these metrics.

However, when we look at these two definitions of success together, it seems that friend dyads, although more efficient, are less accurate than stranger dyads. Prior social familiarity between members of friend dyads is likely to have contributed strongly to their ease of communication, which could have led to more efficient travel. Looking at pausing may provide a clue into this behavior. Although GPS recordings are only available for a subset of all participants in the three studies, I assessed the overall walking speed of participants throughout navigation as well as their pausing or slowing down behavior. Average walking speed of participants across the studies, approximately 2.8 MPH, matches the 1.3 meters per second (approximately 2.9 MPH) reported for the mean adult free walking speed in the literature (e.g. as described in Mohler et al. [101]). Walking while wayfinding may also be expected to be slightly slower than typical walking. Participants were considered to have slowed down or paused when their speed dropped below 1.5 MPH, about half of their average speed. However, as reported in Chapter 6, there were no significant differences between stranger dyads, friend dyads, and individuals on travel speed or duration of pauses for the available data.

Differences in route plans are likely to have contributed to later success during the enacted navigation. The number of unique plans varied across the three studies. Friend dyads overall reported the highest number of unique route plans after the planning phase, but most participants across all three studies showed evidence of considering back-up or alternate plans. Past work on spatial cognition has often restricted participants to an assigned route, but allowing participants to come up with their own route plans demonstrates both the diversity of options available to people within a relatively constrained study environment and the diversity of relevant considerations when selecting routes. For instance, one of the key issues that participants considered was the feasibility of following specific route plans, based not only on the nature of the physical environment but also on their own ability to remember and recognize the features of the route plan.

Future work should consider pausing behavior more systematically, as there appeared to be differences between stopping to plan and planning while continuing to make forward progress. Prior literature has identified this practice as well [20]. At different points, the same dyad or individual may have switched between pausing and continuing while revisiting their plans or the suitability of the ongoing route. Clearly this is not only in order to communicate with one's partner, as individuals also sometimes stopped to think and plan. An in-depth assessment of this pausing behavior could help us understand how this compares between subjects as well as within-subjects at different points in the wayfinding.

7.2 Individual Differences in Dyadic Wayfinding

For the dyadic studies, my research questions concerning individual differences asked whether individuals' sense of direction and personality measures related to dyadic route planning and navigation, examined both as overall characteristics of dyads and as differences between dyad members. With regards to these questions, it does not appear that individual differences in sense of direction, as measured by the Santa Barbara Sense of Direction self-report questionnaire [49], contribute much to overall success for either dyads or individuals on these prospective planning and situated navigation tasks. However, it is interesting to note that SBSOD measures did correlate negatively with degree of route overlap for dyads, in that both stranger and friend dyads with higher self-reported sense of direction followed their routes less closely. This supports the idea that wayfinders with a higher regard for their sense of direction abilities may have higher confidence during navigation, thereby trying potential shortcuts more often or being more inclined to plan complex paths than are lower confidence wayfinders. Higher confidence wayfinders may also be more inclined to adjust their navigational plans in the situated context. This could be an indicator of being less risk-averse in one's navigation behavior, at least when acting as the member of a dyad (this relationship between SBSOD and route overlap was non-significant for solo wayfinders). Sense of direction has been shown to validly predict survey abilities, and accordingly higher sense of direction wayfinders may demonstrate more shortcutting and use of directional cues [49].

The navigation task presented in these studies was primarily dependent on route learning and following, and may therefore only relate minimally to survey abilities. The differences between route following, which depends on an egocentric (viewpoint-dependent) frame of reference and layout learning from a map, which engages allocentric, survey type spatial abilities [42], may account for why the SBSOD did not appear to predict performance in this set of studies. Although it is possible to use a directional (more survey knowledge dependent) strategy to approach the navigation in this task, it appears that many did not, and instead approached it as a route following task, excepting the minimal use of novel shortcuts.

Personality characteristics, as measured by the Big Five personality dimensions of *Extraversion*, *Agreeableness*, *Conscientiousness*, *Neuroticism*, and *Openness to Experience*, did not correlate significantly with the navigational success metrics measured (time and distance overall or to first stated destination location). For the dyad studies (Studies 1 and 2), I compared both dyad average scores and differences in scores to success metrics. The sample size appears to be too low in the two dyad studies to find significance in the relationships between personality and success on the task. Any relationships with personality dimensions may indeed have a small effect size, considering the size of the correlations as reported in Chapters 3 and 4. For the individuals study (Study 3), described in Chapter 6, higher scores on Openness to New Experience was significantly related to poorer performance, as was Conscientiousness. This seems to be consistent with the trend described above in relation to SOD, in that individuals with higher Openness or Conscientiousness may have more confidence in planning complex routes or trying shortcuts during navigation. In my three studies there were no direct, reliable relationships between sense of direction and personality, although prior work with notably larger samples has shown such associations [57].

7.3 Challenges of Coordination and Communication

Dyads in these studies faced a number of challenges related to communication. It was necessary in this collaborative wayfinding task for the dyad to jointly coordinate their knowledge at several stages throughout the study. This involved the challenges of establishing a common understanding of the environment, initially through the shared use of the paper map, as well as a common understanding of the agreed-upon route (or possible routes) between the origin and destination points.

Initially, participants began with the use of the paper map as a joint resource shared between the dyad members. This external resource – i.e. external to themselves – served as the main navigational aid used during planning. Dyads at this stage already faced a number of challenges, including the social challenge of reaching consensus about competing possible route plans, despite uncertainty about certain aspects of the map. Uncertainty was evident mainly with respect to the identity of landmarks on the map, dyads' ability to recognize necessary landmarks as cues within the situated context, memory for the route plan(s), and potential connectivity between certain roads, paths, or areas on the map for shortcutting opportunities.

Although Denis [108] discusses the potential for route selection to be partially constrained by communicability—the ease or difficulty in communicating a route to another person—it is unlikely that this has a strong impact on route choices in this work. Dyads and individuals in all three studies were given adequate time to plan and did so with the aid of a paper map, which was used as a communicative resource continuously throughout planning. Although participants spoke aloud and to their partners to propose routes, much of the verbal planning process was accompanied both by representative gestures and references to parts of the map. Results also showed that most participants considered and discussed a number of routes before selecting a primary course of action. However, Denis points out that much of route planning appears to be pre-verbal, which would help account for why individuals and members of dyads often began to plan silently before beginning either the think-aloud protocol or communication with one's partner.

Although each dyad worked first with a paper map as an external aid to route planning, once they were within the environment for situated navigation, the map was not available to them. Additionally, the environmental scale of the study site did not allow for the entire area to be viewed from any given perspective (e.g. they could not see the destination from the origin). Therefore, the members of the dyad had to refer to the route plan and the map representation of the environment during navigation without being able to physically point at an external representation. Dyads in these studies used a variety of communicative modalities to make these spatial references, most commonly talk and gesture, but were occasionally aided by external tools like drawings made with sticks in the dirt. Not only did dyads need to ensure they were referring to the same internal representation of their route or of the study area, they often had to reach agreement with some level of personal and social doubt about their memorization of their plan.

In addition to the dyadic challenge of remembering and socially coordinating spatial knowledge with one's partner, individuals and dyads had to perform the complex task of understanding the correspondence between the map and the experienced environment. They had to use both self-localization and map correspondence to understand how the locations where they were physically located related to the locations along their route plan and the previously-viewed map, which is more complex than directly locating themselves on a map while viewing it (e.g. Peruch et al. [109]). This is especially challenging when translating between the survey perspective of the paper map and the egocentric viewpoint within the environment.

Additionally, the type of route planning and navigation tasks featured in these studies may not be universally familiar to my participants, who were almost all young adults. Although no systematic survey of participants' GPS use and familiarity with paper maps was conducted, at least a few participants did mention *no* prior experience with using a paper map and several participants mentioned high GPS-dependence for their day-to-day navigational routing, even while driving regular routes. The availability and ubiquity of common digital map applications, like Google Maps and others, especially for mobile navigational use, are responsible for these changes in daily mobility behavior. This technological mediation of spatial behavior in daily life is likely to have an effect on individual spatial experience and spatial ability over the lifespan [45], so it would not be surprising to see a decline in spatial ability in younger generations (comparing those who have had unfettered access to mobile navigational aids versus those who have not). Those who have had prior experience selecting a route on one's own or with others, versus having it selected for them, would likely have an advantage in such a task as presented here.

7.4 Facing Navigational Challenges Together

Dyads and individuals employed a number of strategies to deal with navigational challenges they encountered in the situated context. Some were common across both dyads and individuals, such as flexibly adapting their route plans based on the wayfinding considerations made relevant in real-time. However, dyads had more social resources for dealing with problems, as they consulted often with their partners at decision points en route and relied on each other to help remember aspects of their plan or the environment. This helps explain why more solo navigators got lost during navigation and may have been more likely to give up entirely.

Social interaction, however, likely also has associated costs, such as the cost of increased cognitive load. For instance, considerations of social reputation are never entirely absent, even in the context of participating in a research study. Participants may hesitate to express or admit uncertainty to their partners, and this may be more or less pronounced between friends. Study 2 likely did not collect enough background about the social relationships between the recruited friend dyads to say exactly why that may have occurred here. I collected very little background information about the dyads with prior friendship in Study 2, other than their length of friendship and a coarse self-report of their level of prior familiarity. For example, it is likely that romantic couples differ from friends (even close friends) in important ways that could impact wayfinding behavior. Additionally, when people are under greater levels of stress, the social treatment and communication of uncertainty within dyads would make the situation quite different than when traveling solo, especially when errors of navigation have potentially dangerous consequences [110].

Leadership behavior during planning and navigation is an important window into the enactment of sociality during wayfinding. Dyads in these studies were strangers with little or no prior familiarity in Study 1, and friends with at least 1 year of prior familiarity in Study 2. However, as only a few of the dyads were those in long term relationships in which they primarily travelled with one another, I expect that those in longer-term, committed relationships with frequent co-travel would be much more established and rarely at-risk of changing through one-off displays of competence. People are also expected to have varying levels of *motivation to lead*, as theorized by Chan and Drasgow [111]. Social leadership during wayfinding is likely to depend on a wide variety of factors, including individual differences in spatial abilities and personality. It seems important that dyads, as well as larger social groups, reduce barriers to expressing uncertainty to improve relevant communication during wayfinding. Therefore, socially mediated responses to navigational challenges, such as through leadership behavior, is an important area for further inquiry.

Beyond leadership and role-taking, it appears from the first two studies that prior friendship facilitates social communication within the dyad during wayfinding. This is supported in the chapter on conversational interaction (Chapter 5). Friend dyads, stranger dyads, and individuals all demonstrated to some degree that they recognized the need for adaptive prospective planning, but friend dyads more often pre-emptively planned to consider alternatives. Friends were more willing to express personal uncertainty and to disagree when it was useful to do so, such as when necessary to re-establish joint understanding of the plan and its progression. Strangers had a greater tendency to continue moving 'forward' if no issue was raised, and there appeared to be a higher social barrier to individual members of stranger dyads raising such issues with their partners. These general patterns compounded the potential problems in completing the wayfinding task successfully, as it was easy for dyads to become more disoriented if navigation problems were not addressed early. Therefore, although it is important to group success to reduce barriers to expressing social uncertainty through open communication, one's social reputation, or at least the semblance of wayfinding competence to one's social partner, appears always to be "on the line." As Garfinkel [112] said, there are no time-outs in social life.

Friends more explicitly questioned (or even challenged) their partner about their level of certainty during en route decision-making than did strangers. However, as I find in the Conversation Analysis, both stranger and friend dyads were able to 'bookmark' potential problem areas or decision points of high uncertainty; see my discussion of this practice as *spatial bookmarking* (Section 5.2.4). Bookmarking of critical points along the route can be done socially (in conversation with one's partner) or individually (making an internal note to oneself) by members of a dyad, so it is unclear how much it is employed when it is not communicated. It is also likely that participants in the study have widely varying levels of tolerance for uncertainty, which may relate to spatial anxiety in this task. The only measure I believe could have accounted for this difference in tolerance is the Openness to New Experience dimension of the Big Five personality inventory, but the inclusion of a spatial anxiety measure in future work would be useful here [50].

7.5 Shortcomings

There are a number of shortcomings that need to be addressed with respect to the current work, to be considered in future work. These include details about the research design, the sampling method, the imbalance of gender across dyads and individual participants, and the analysis of social interaction in these studies.

7.5.1 Research Design

A larger sample of participants would have allowed me to investigate sense of direction and personality differences to a greater extent than I was able to in these three studies. Even with the smaller samples (30 dyads in Studies 1 and 2; 30 individuals in Study 3), I was only able to see a few significant associations between SOD and navigational success. However, the low statistical power associated with these smaller samples reduces the ability to detect true effects. With a larger sample size, we could expect a greater range of personality attributes in the participant pool and perhaps also have assigned participants to dyads counter-balanced by those attributes. It would then have been more possible to parse which Big Five characteristics are associated with specific behaviors such as navigational leadership or flexible planning.

The study area was a suburban residential neighborhood, selected both for its proximity to campus and its complex spatial layout (allowing many alternate routing possibilities). Some of the categories of conversational interaction, as reported in Chapter 5, may have been fairly specific to the study environment used across the three studies and therefore only partially generalize to other types of neighborhoods or physical environments. For instance, participants working on the same task in less human-made or constructed environments may orient to different types of cues and face additional (or different) challenges during situated navigation. Therefore, not carrying out the study in a variety of environments serves as another limitation.

In terms of methodology for the individuals study, there are important shortcomings to the think-aloud protocol. I implemented this protocol to make Study 3 more comparable to Studies 1 and 2, and to generate some verbal transcripts for CA. First, as there was no condition in which individuals were *not* asked to talk out loud about their planning and navigational thought processes, it is difficult to know whether the think-aloud task helped or hindered individuals, and whether it felt 'natural' to do so. If, for instance, wayfinding individuals tend to think aloud without being asked to do so, it is possible that it serves as a cognitive aid to remembering, by organizing or clarifying their thought process. Second, performing a think-aloud protocol may have increased cognitive load for individuals, which could account for part of the poorer performance by individuals as compared to dyads. Little is known about how the mental work of a think-aloud protocol directly compares with that of direct social communication with a partner.

7.5.2 Diversity in the Research Pool

One common critique of behavioral studies such as these, which draw participants from a pool of university students, is the lack of diversity in the research pool [113]. Age and cultural diversity were quite limited across the participants of the three studies. Participants were recruited from the UC Santa Barbara Geography Research Pool, which typically draws its students from introductory-level courses offered by the Department of Geography. The majority of these students are not Geography majors but come from majors across campus. All participants were undergraduate students, typically ranging 18 to 22 years of age, many in their first or second year of undergraduate education. This explains why the average age in each of the studies was fairly low: the average for Study 1 was 19.5 years (SD = 2.1; range 18 to 33); for Study 2 was 19.1 years (SD = 1.4; range 18 to 25); and for Study 3 was 20.7 years (SD = 2.1; range 18 to 25).

Prior research in spatial cognition with relation to development and aging shows that spatial abilities change over the lifespan [114]. Younger adults, such as those in my studies, may be better able to flexibly switch or adapt their wayfinding strategies, as Harris and Wolbers showed in their study of egocentric route-following versus allocentric strategy in young and older adults [115]. The novel shortcutting behavior that was sometimes exhibited in my studies may be less frequently employed by older adults. Therefore, my findings about real-world collaborative spatial navigation in younger adults would need to be compared to the navigation of older adults to understand wayfinding strategy differences across age groups.

Cultural—and potentially socioeconomic and ethnic—diversity were likely to be limited by our sampling method. Although I did not ask participants directly about cultural, socioeconomic, or ethnic identity, nor did I collect other demographic or socioeconomic information, a fluent understanding of English was required for participation in the study and so may have been a barrier for some (but certainly not all) international students. As reported in the most recent campus profile (2019–2020) from Institutional Research, Planning & Assessment [116], 14% of the UC Santa Barbara undergraduates enrolled were international students, and a distinct majority of those students (75%) are from China. Since many of the domestic undergraduate students at UCSB are from California (83%) and many of those from Central and Southern California (51% of those from California), the research pool accordingly may represent limited cultural diversity.

In terms of ethnicity, the undergraduate ethnicity breakdown in the 2019 to 2020 academic year for domestic students at UCSB was 35% white, 29% Chicano/Latino, 28% Asian/Pacific Islander, 5% Black/African American, and less than 5% all other groups [116]. This work would benefit from future collaborations which take into account cross-cultural diversity in social wayfinding behavior, a rich area of research considering the recognized diversity in human sociality [117, 118] and possibly also in spatial thinking [119, 120, 121, 122].

7.5.3 Gender

The uneven gender balance of participants and small sample sizes within each of the studies did not allow for reliable conclusions attributable to gender alone. In Study 1, female-female dyads were 50% of the friend pairs, female-male dyads were 43% of the pairs, and male-male dyads were 7% of the pairs. In Study 2, female-female dyads made up 43% of the stranger pairs, female-male dyads made up another 47%, and the remaining 10% were male-male pairs. Study 3 was more balanced by gender, with female participants comprising 57% of the individual participants.

As pairs in Study 1 were only randomized by sign-up time and not assigned to timeslots based on the distribution of gender pairings, the higher proportion of female students in the research pool as well as the low overall number of subjects resulted in very few male-male dyads. Research sign-ups were not restricted based on gender, although female students may have been more likely to sign up for study participation. Dyad partners in Study 2 were self-selected, and participants were only told to sign-up with a friend, without specification about what gender their friend should be. This is a shortcoming due to the design of the research recruitment and should be addressed in any future work. Gender is especially likely to have played an important role in the social interactive components of this research. It may also have affected basic physical considerations, such as walking speed [102].

Sex and gender differences are important with regard to spatial wayfinding anxiety. It is possible that the ability to remember and carry out a route plan within a real environment may relate to general spatial anxiety (which may indeed relate to self-reported personality characteristics as well). Some studies show women tend to report greater levels of spatial anxiety [84], which may manifest in the context of real-world wayfinding as an anxiety about forgetting the route or getting off-course and risking becoming lost [66]. Thoresen et al. [123] found that trait anxiety has a negative impact on route learning for male participants with low mental rotation ability. Anxiety may then hinder spatial abilities in a way that impacts navigation or route planning strategies, as in the three studies presented. For instance, higher spatial anxiety may lead to greater risk aversion in selection of routes. However, as participant anxiety was not assessed directly, I can only assume it was present in varying degrees. Working with a partner, whether a stranger or a friend, is likely to moderate the relationship between wayfinding anxiety and performance. Additionally, the uneven ratios of females to males across my studies reduced my ability to assess gender differences in more detail.

Cultural differences in spatial navigation are also important avenues for further research. Anthropological studies, such as by Cashdan et al. [124] have shown that sex differences can exhibit themselves differently in foraging versus nonforaging populations, showing the importance of understanding gender in the context of culture and life experience. Other cross-cultural factors, as mentioned above, are likely to impact gender roles and sex-differentiated development of spatial cognitive abilities. This again restates the need for greater cultural diversity in this and future research programs in spatial cognition.

7.5.4 Social Interaction Analysis

There are several approaches to social discourse analysis that may potentially be applied to wayfinding contexts, from sociology, cognitive linguistics, and related fields. Given the focus of Conversation Analysis (CA) on naturally-occurring social interactions, it is well suited to more ecologically valid scenarios such as the tasks presented in my three studies, which take place both in a real world, large-scale environment and in a realistic social context. Other approaches include Cognitive Discourse Analysis (CODA

[125, 126]), which can also be applied to video-recorded collections such as this one; it focuses on how language can reveal underlying cognitive representations (such as spatial frames of reference).

Although I use CA in this work, there are methodological shortcomings worth addressing here. For one, CA typically deals with video- and/or audio-recordings of naturally occurring conversation, rather than interactions taking place in an "experimental" study setting such as this. Therefore, the observed actions in these studies may differ from naturally occurring wayfinding interactions in important ways: the dyads know they are participating in research on wayfinding, are meeting for the first time (in the case of stranger dyads in Study 1), are asked to work together, and may experience behavioral reactance from knowing they are being observed and video-recorded. Though this does not invalidate the application of this method to this set of recordings, I recognize that aspects of sequential organization are potentially shaped by these features of the scenario—especially if participants show that they orient to them.

Many open questions remain with regard to my assessment of social interaction during wayfinding. Partner familiarity and established social roles are likely to have played a bigger role in the friend dyads than was discussed. It is important to explore the extent to which existing social relationships impact who makes the first suggestions during route planning or takes the lead during navigation (a question of epistemic rights in the context of wayfinding [127]). There is little prior context to assert whether existing social relationships hold true generally for all types of social interactions, and therefore have high transfer to the navigational context. It is certainly possible that leader and follower roles in wayfinding differ from the social roles established within the dyad for other kinds of decision-making.

7.6 Contributions to Spatial Cognition

In these three studies, I detail important patterns of social and spatial behavior with regard to wayfinding in a novel environment, with or without a partner. Wayfinding as part of a dyad appears to be fundamentally different than wayfinding as an individual in a number of ways. The social structure of a dyad itself, such as between a stranger dyad and a friend dyad, may additionally impact wayfinding practices and success. Previous literature shows that this is a fruitful avenue for exploration, and the set of studies in this dissertation contributes to our understanding of how sociality impacts human wayfinding behavior.

There are important differences between learning a route in order to physically carry it out once between an origin and destination (as done here) versus learning the route to encode it accurately for longer-term spatial learning (e.g. Ishikawa & Montello [37]), such as for later reproduction or description. In these studies, participants were not asked to produce a representation of the route after the navigation phase, such as by sketching a map or a route. Doing so may have elicited interesting differences between embodied route learning over the course of real-world navigation and static map-based route learning. If participants had received feedback they could have better calibrated their spatial knowledge in future sessions, which may have led to improvements in navigational success. Certainly this points to the importance of feedback, such as on useful spatial strategies, to improving spatial cognition in the context of navigation. Potentially, feedback from a social partner (such as during planning) could be applied to improving individuals' spatial knowledge in the environment even on their initial journey through a new environment. Additionally, by providing metric or directional cues or highlighting important cues for people to attend to within the environment, we could potentially improve navigational support systems or improve wayfinding maps.

The complexity of human behavior in groups calls for interdisciplinary methods of inquiry and approaches to understanding, such as has been demonstrated here. By bringing together the diverse methodologies and ways of knowing represented by geography, psychology, and sociology, I investigate wayfinding behavior in both a real physical and social context. In doing so, I find ways in which social behavior influences dyads' planning of routes and the enactment of routes in the context of navigation through a novel environment. This serves as a fruitful step towards future work in this area, which should further consider the impacts of social context as situated in real environments.

Appendix A

Study 1

A.1 Institutional Review Board (IRB) Consent Form

See following page.

Consent to Participate in Research

Protocol Number: 49-17-0851
Approved by the UCSB Human Subjects Committee for use thru: 10/16/2018

PURPOSE: You are being asked to participate in a research study. The purpose of the study is to understand how pairs of people work together to find their way through a new environment. We are exploring how navigation performance is affected by social interaction with the wayfinding partner.

PROCEDURES: If you decide to participate, we will ask you to work with a randomly-assigned partner to plan a route through a new environment with a map, describe that route to the researcher, and then navigate the route in person with your partner in that environment. You will be video-recorded during the planning and navigation phases, and during navigation you will also wear a small video camera and carry a GPS device. For the navigation phase, you and your partner assigned in the study will be driven by the researcher to a local Goleta neighborhood. You will also complete pre- and post- surveys as part of your participation.
The duration of this study is approximately 1.5 hours to complete all tasks. You will be one of approximately 60 total participants in this study.

RISKS: This study requires physically navigating through a new environment on foot, which means you will be exposed to typical risks associated with walking around a neighborhood. Please inform the researcher if at any point you feel uncomfortable continuing this task.

BENEFITS: Results of this study are expected to expand our knowledge of how people plan a route and navigate together in a new environment. Additionally, as a participant you will have the opportunity to learn more about a local neighborhood in Goleta.

CONFIDENTIALITY: All video- and audio-recordings taken during data collection for this study will be stored securely and password protected for use in analysis. Faces or identifiable images will be obscured if shared with anyone other than the Principal Investigators or Research Assistants. Absolute confidentiality cannot be guaranteed, since research documents are not protected from subpoena.

RIGHT TO REFUSE OR WITHDRAW: You may refuse to participate and still receive any benefits you would receive if you were not in the study. You may change your mind about being in the study and quit after the study has started. The investigator may withdraw participants from the study at his/her discretion.

QUESTIONS:
If you have any questions about this research project or if you think you may have been injured as a result of your participation, please contact: Dr. Daniel Montello at (805) 893-8536 or montello@ucsb.edu

If you have any questions regarding your rights and participation as a research subject, please contact the Human Subjects Committee at (805) 893-3807 or hsc@research.ucsb.edu. Or write to the University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050

PARTICIPATION IN RESEARCH IS VOLUNTARY. YOUR SIGNATURE BELOW WILL INDICATE THAT YOU HAVE DECIDED TO PARTICIPATE AS A RESEARCH SUBJECT IN THE STUDY DESCRIBED ABOVE. YOU WILL BE GIVEN A SIGNED AND DATED COPY OF THIS FORM TO KEEP.

Signature of Participant or Legal Representative:___________________________________
Date:_______________Time:____________

A.2 Protocol

See following pages.

Study 1 Protocol

1. Recruitment and Pre-Study Questionnaire

After two participants are signed-up for a timeslot and at least 24 hours before timeslot, assign each person a unique Participant ID (PID) and send link to online Pre-Study Questionnaire with PID by email.

Online questionnaire collects the following:

- Age of participant
- Sex of participant
- Familiarity rating with Goleta area
- Santa Barbara Sense of Direction (SBSOD)
- Big Five Inventory (BFI)

Send reminder email with meeting location and scheduled time the day before, and a reminder about the online questionnaire if they have not yet filled out the forms.

2. Meeting in the Geographic Cognition Lab [10 minutes]

Before participants arrive: Park car in closest legal space to the lab. Unlock and prepare lab area, set up video camera position (keeping OFF until Phase 1), and gather paper materials and pens for participants.

Greet and thank participants for signing up to participate. Reschedule participant if partner is a no-show. Once both participants arrive, administer Consent Form:
"This sheet explains the purpose and nature of this study. Please read through and sign at the bottom if you agree to participate in the study. If you have questions about any part of this, let me know."

Assess partner familiarity: "Since you will be working together in this study, I need to mark down your prior familiarity with one another. Do you already know each other?"

- If YES, ask "How well do you know each other?" and record rating # on Partner Familiarity sheet.
- If NO, mark 0 for both on notes sheet.
- Allow participation if 1 or 2 rating for both participants.

Assess familiarity with study site (Storke Ranch): "Next, I will show you an area on this map which is the area we will be using for this study. [Indicate to participants on map.] This is a residential area called Storke Ranch, which is north of El Colegio Road and just east of Storke Road. It is located just to the north of the Santa Catalina residence hall. Please describe your prior familiarity with Storke Ranch, to the best of your knowledge."

- Write rating # for each participant on Site Familiarity sheet.
- Allow participation if 1 or 2 rating for both participants.

3. Phase 1: Prospective Planning [20 min]

Tell participants about video-recording: "Thank you. This planning part of the study will be video-recorded." [turn on and set-up camera above and far enough back to see both participants' faces and the map on the table]

At table in front room, instruct participants to plan route together:
"Now, the two of you will be working together using a paper map to plan a route that you will have to walk in the next part of the study - without the map. Working with your partner and using the provided map only, please plan a pedestrian route to take between these marked origin ("O") and destination ("D") locations shown on the map [point to each on the map], minimizing as much as possible the distance and time to reach the destination. Make sure you remember your planned route, as you will *not be able to use this or any other map* when you walk through the environment in the next part of this study."

- Sit at side table and observe participants' planning - make notes of anything unique or unexpected.
- Stop if still planning after 10 minutes.

Collect individual descriptions of the route: "In this next part, I will ask you about the route you planned. You will be doing this individually, so I will first start by asking [participant A name] to come into a separate room with me. [Participant B name], you can wait here, use your phone or go to the bathroom if needed, but please do not look at any other maps."

- Take video camera and lead participant to the back room with main door closed.
- Instruct participant to draw and verbally describe the planned route: "On this map, please draw and describe in words the route that you and your partner have planned to take between the origin and the destination." Video-record showing the map, no need for face.

This next phase leaves the lab and takes place in the actual study site.

4. Phase 2: Situated Navigation [10 min for travel, up to 30 min for dyad navigation, 5-10 min for questionnaire and debriefing, 10 minutes to travel back]

Drive dyad to study site (Storke Ranch). Park at or near origin as availability allows. Offer participants the chance to leave belongings in car trunk if desired. Set up each participant with chest-mounted video camera, then prepare researcher video camera and GPS tracker.

Walk dyad to start. Instruct participants: "In this part of the study, you will work with your partner to follow your planned route between the origin and destination locations you previously saw on the map. You will wear a small video-camera and will also be video-recorded by the researcher as you navigate through the environment. You are not allowed to use your cell phone or another map to help you navigate, only what you remember and see in the environment. No need to follow the route as planned before, but work with your partner to take the best possible route to reach the destination. When you and your partner feel that you have reached the destination point, please let me know. You will have 30 minutes to complete this task."

Ask participants to start video recording and begin. Start researcher video camera and GPS recorder at the same time. Dyad navigates on foot the planned route. [30 min max]

- Dyad observed and video-recorded by researcher, who will **verbally note** times and approximate locations of activities, such as where the dyad stops or ventures off-route, mainly activities which help mark significant actions in the video or those not likely to be picked up on video.
- If dyad attempts (checks) 2 times at an incorrect destination point, tell them "You can try one more time to reach the destination."

- If 3rd attempt is still incorrect OR if dyad reaches time limit of 30 minutes without having successfully reached the destination, stop recordings, then lead participants to either picnic tables or origin point (car) to complete Post-Navigation Survey. Make note on one of the maps that participants did NOT reach destination.

At end point, stop all video and GPS recordings. Lead participants to picnic tables near end point to individually complete Post-Navigation Survey. [approx. 5-10min]

- Instruct participants: “Now that you have completed the navigation task, I will ask you to individually fill out this survey based on your experience today.”
- Debriefing: “Thank you. Both of you have helped contribute to research on the understanding of how people work together to navigate. Here is the route the two of you took today during this navigation phase. [Show them on one of the maps. Explain the route they chose versus the shortest route, if interested.] Do you have questions about anything you did today as part of the research?”

Walk participants back to starting point and car, using path through open area. Drive participants back to campus. Thank participants, then give participation credit on the Research Pool system.

Materials

- online Pre-Study Questionnaire: http://geog.ucsb.edu/researchpool/participate/
- clipboard(s) with 2 copies each of printed materials:
  - Consent Form
  - Alternative (paper) copies of Pre-Study Questionnaire
  - Partner Familiarity
  - Site Familiarity (and zoomed-in map)
- For Phase I (Planning):
  - master copy of map of study site
  - video camera
  - 2 copies of maps for route sketches
- For Phase II (Navigation):
  - 2x GoPro Hero 3 video cameras for participants with chest mount
  - handheld Sony video camera for RA
  - cell phone with GPS tracking application “GeoTracker” (keep extra phone battery and Garmin as backup)
  - 2 copies of Post-Navigation Survey, clipboards, and pens

A.3 Forms and Questionnaires

See following pages.

Santa Barbara Sense-of-Direction Scale

Sex: F M   Today's Date:________________
Age:_______   V. 2

This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree, or some number in between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

1. I am very good at giving directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

2. I have a poor memory for where I left things.

strongly agree 1 2 3 4 5 6 7 strongly disagree

3. I am very good at judging distances.

strongly agree 1 2 3 4 5 6 7 strongly disagree

4. My "sense of direction" is very good.

strongly agree 1 2 3 4 5 6 7 strongly disagree

5. I tend to think of my environment in terms of cardinal directions (N, S, E, W).

strongly agree 1 2 3 4 5 6 7 strongly disagree

6. I very easily get lost in a new city.

strongly agree 1 2 3 4 5 6 7 strongly disagree

7. I enjoy reading maps.

strongly agree 1 2 3 4 5 6 7 strongly disagree

(over)

8. I have trouble understanding directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

9. I am very good at reading maps.

strongly agree 1 2 3 4 5 6 7 strongly disagree

10. I don't remember routes very well while riding as a passenger in a car.

strongly agree 1 2 3 4 5 6 7 strongly disagree

11. I don't enjoy giving directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

12. It's not important to me to know where I am.

strongly agree 1 2 3 4 5 6 7 strongly disagree

13. I usually let someone else do the navigational planning for long trips.

strongly agree 1 2 3 4 5 6 7 strongly disagree

14. I can usually remember a new route after I have traveled it only once.

strongly agree 1 2 3 4 5 6 7 strongly disagree

15. I don't have a very good "mental map" of my environment.

strongly agree 1 2 3 4 5 6 7 strongly disagree

The Big Five Inventory (BFI)

Here are a number of characteristics that may or may not apply to you. For example, do you agree that you are someone who likes to spend time with others? Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement.

Disagree strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree strongly
1	2	3	4	5

<u>I see Myself as Someone Who</u>...

___1. Is talkative

___2. Tends to find fault with others

___3. Does a thorough job

___4. Is depressed, blue

___5. Is original, comes up with new ideas

___6. Is reserved

___7. Is helpful and unselfish with others

___8. Can be somewhat careless

___9. Is relaxed, handles stress well

___10. Is curious about many different things

___11. Is full of energy

___12. Starts quarrels with others

___13. Is a reliable worker

___14. Can be tense

___15. Is ingenious, a deep thinker

___16. Generates a lot of enthusiasm

___17. Has a forgiving nature

___18. Tends to be disorganized

___19. Worries a lot

___20. Has an active imagination

___21. Tends to be quiet

___22. Is generally trusting

___23. Tends to be lazy

___24. Is emotionally stable, not easily upset

___25. Is inventive

___26. Has an assertive personality

___27. Can be cold and aloof

___28. Perseveres until the task is finished

___29. Can be moody

___30. Values artistic, aesthetic experiences

___31. Is sometimes shy, inhibited

___32. Is considerate and kind to almost everyone

___33. Does things efficiently

___34. Remains calm in tense situations

___35. Prefers work that is routine

___36. Is outgoing, sociable

___37. Is sometimes rude to others

___38. Makes plans and follows through with them

___39. Gets nervous easily

___40. Likes to reflect, play with ideas

___41. Has few artistic interests

___42. Likes to cooperate with others

___43. Is easily distracted

___44. Is sophisticated in art, music, or literature

Please check: Did you write a number in front of each statement?

Study Date/Time: ___________

Partner Familiarity

Since you will be working together in this study, I need to mark down your prior familiarity with one another. Do you already know each other?

<u>If so</u>: *How well do you know each other?*

Participant ID: ______
Participant Sex: _____

- ○ 0 = no familiarity
- ○ 1 = acquaintances, such as classmates or shared activities
- ○ 2 = occasionally spend time together outside of a class context
- ○ 3 = I would consider this person a friend

Participant ID: ______
Participant Sex: _____

- ○ 0 = no familiarity
- ○ 1 = acquaintances, such as classmates or shared activities
- ○ 2 = occasionally spend time together outside of a class context
- ○ 3 = I would consider this person a friend

Pre-Study Familiarity Questionnaire

Before your study begins, we require the following information.

Rate your familiarity with the following area labeled "Storke Ranch neighborhood" on the map, with the number 1 meaning "very unfamiliar" and 5 meaning "highly familiar".

Participant ID: ______

- ○ 1 = very unfamiliar
- ○ 2 = unfamiliar
- ○ 3 = somewhat familiar
- ○ 4 = familiar
- ○ 5 = highly familiar

Participant ID: ______

- ○ 1 = very unfamiliar
- ○ 2 = unfamiliar
- ○ 3 = somewhat familiar
- ○ 4 = familiar
- ○ 5 = highly familiar

Post-Navigation Survey

During navigation in the environment with your partner…

1. Did you and/or your partner take a path that was different from your planned route in any way? Describe if so.

2. Did anything unexpected happen (related to your navigation) while you and your partner were walking along your route? If so, what was unexpected?

3. Who acted more as the navigational leader? (circle one)
    a. I was leading more
    b. my partner was leading more
    c. neither was clearly leading more

4. Were there any points during which you felt lost or unsure about the route? If so, describe.

5. At any point did you and your partner disagree about the way to go? If so, describe.

Appendix B

Study 2

B.1 Institutional Review Board (IRB) Consent Form

See following page.

Consent to Participate in Research

Protocol Number: 49-19-0805
Approved by the UCSB Human Subjects Committee for use thru: 10/10/2020

PURPOSE: You are being asked to participate in a research study. The purpose of the study is to understand how pairs of people work together to find their way through a new environment. We are exploring how navigation performance is affected by social interaction with the wayfinding partner.

PROCEDURES: If you decide to participate, we will ask you to work with a partner to plan a route through a new environment with a map, describe that route to the researcher, and then navigate the route in person with your partner in that environment. You will be video-recorded during the planning and navigation phases, and during navigation you will also wear a small video camera and carry a GPS device. For the navigation phase, you and your partner will be driven by the researcher to a local Goleta neighborhood. You will also complete pre- and post- surveys as part of your participation. The duration of this study is approximately 1.5 hours to complete all tasks. You will be one of approximately 60 total participants in this study.

RISKS: This study requires physically navigating through a new environment on foot, which means you will be exposed to typical risks associated with walking around a neighborhood. Please inform the researcher if at any point you feel uncomfortable continuing this task.

BENEFITS: Results of this study are expected to expand our knowledge of how people plan a route and navigate together in a new environment. Additionally, as a participant you will have the opportunity to learn more about a local neighborhood in Goleta.

CONFIDENTIALITY: All video- and audio-recordings taken during data collection for this study will be stored securely and password protected for use in analysis. Faces or identifiable images will be obscured if shared with anyone other than the Principal Investigators or Research Assistants. Absolute confidentiality cannot be guaranteed, since research documents are not protected from subpoena.

RIGHT TO REFUSE OR WITHDRAW: You may refuse to participate and still receive any benefits you would receive if you were not in the study. You may change your mind about being in the study and quit after the study has started. The investigator may withdraw participants from the study at his/her discretion.

QUESTIONS: If you have any questions about this research project or if you think you may have been injured as a result of your participation, please contact: Dr. Daniel Montello at (805) 893-8536 or montello@ucsb.edu

If you have any questions regarding your rights and participation as a research subject, please contact the Human Subjects Committee at (805) 893-3807 or hsc@research.ucsb.edu. Or write to the University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050

PARTICIPATION IN RESEARCH IS VOLUNTARY. YOUR SIGNATURE BELOW WILL INDICATE THAT YOU HAVE DECIDED TO PARTICIPATE AS A RESEARCH SUBJECT IN THE STUDY DESCRIBED ABOVE. YOU WILL BE GIVEN A SIGNED AND DATED COPY OF THIS FORM TO KEEP.

Signature of Participant or Legal Representative:__________________________________
Date:_______________Time:____________

B.2 Protocol

See following pages.

Study 2 Protocol

1. Recruitment and Pre-Study Questionnaire

Participants are informed through the Research Pool that they are required to sign up with a partner that they have known for at least one year (12 months).

After one participant is signed-up for a timeslot and at least 24 hours before timeslot, assign each person a unique Participant ID (PID) and send link to online Pre-Study Questionnaire with PID by email.

Online questionnaire collects the following:

- Age of participant
- Sex of participant
- Familiarity rating with Goleta area
- Santa Barbara Sense of Direction (SBSOD)
- Big Five Inventory (BFI)

Send reminder email with meeting location and scheduled time the day before, and a reminder about the online questionnaire if they have not yet filled out the forms.

2. Meeting in the Geographic Cognition Lab [10 minutes]

Before participants arrive: Park car in closest legal space to the lab. Unlock and prepare lab area, set up video camera position (keeping OFF until Phase 1), and gather paper materials and pens for participants.

Greet and thank participants for signing up to participate. Reschedule participant if partner is a no-show. Once both participants arrive, administer Consent Form:
"This sheet explains the purpose and nature of this study. Please read through and sign at the bottom if you agree to participate in the study. If you have questions about any part of this, let me know."

Assess partner familiarity: "Since you will be working together in this study, I need to mark down your prior familiarity with one another. How well do you know each other?"

- Record rating # on Partner Familiarity sheet (score ranges from 1 to 4).
- Allow participation if 3 or 4 rating for both participants.

Assess familiarity with study site (Storke Ranch): "Next, I will show you an area on this map which is the area we will be using for this study. [Indicate to participants on map.] This is a residential area called Storke Ranch, which is north of El Colegio Road and just east of Storke Road. It is located just to the north of the Santa Catalina residence hall. Please describe your prior familiarity with Storke Ranch, to the best of your knowledge."

- Write rating # for each participant on Site Familiarity sheet.
- Allow participation if 1 or 2 rating for both participants.

3. Phase 1: Prospective Planning [20 min]

Tell participants about video-recording: "Thank you. This planning part of the study will be video-recorded. This is only for analysis and will not be shared or posted publicly." [turn on and set-up camera above and far enough back to see both participants' upper bodies and the map on the table]

At table in front room, instruct participants to plan route together:
"Now, the two of you will be working together using a paper map to plan a route that you will have to walk in the next part of the study - without the map. Working with your partner and using the provided map only, please plan a pedestrian route to take between these marked origin ("O") and destination ("D") locations shown on the map [point to each on the map], minimizing as much as possible the distance and time to reach the destination. Make sure you remember your planned route, as you will *not be able to use this or any other map* when you walk through the environment in the next part of this study."

- Sit at side table and observe participants' planning - make notes of anything unique or unexpected.
- Stop if still planning after 10 minutes.

Collect individual descriptions of the route: "In this next part, I will ask you about the route you planned. You will be doing this individually, so I will first start by asking [participant A name] to come into a separate room with me. [Participant B name], you can wait here, use your phone or go to the bathroom if needed, but please do not look at any other maps."

- Take video camera and lead participant to the back room with main door closed.
- Instruct participant to draw and verbally describe the planned route: "On this map, please draw and describe in words the route that you and your partner have planned to take between the origin and the destination." Video-record showing the map, no need for face.

This next phase leaves the lab and takes place in the actual study site.

4. Phase 2: Situated Navigation [10 min for travel, up to 30 min for dyad navigation, 5-10 min for questionnaire and debriefing, 10 minutes to travel back]

Drive dyad to study site (Storke Ranch). Park at or near origin as availability allows. Offer participants the chance to leave belongings in car trunk if desired. Set up each participant with chest-mounted video camera, then prepare researcher video camera and GPS tracker.

Walk dyad to start. Instruct participants: "In this part of the study, you will work with your partner to follow your planned route between the origin and destination locations you previously saw on the map. You will wear a small video-camera and will also be video-recorded by the researcher as you navigate through the environment. You are not allowed to use your cell phone or another map to help you navigate, only what you remember and see in the environment. No need to follow the route as planned before, but work with your partner to take the best possible route to reach the destination. When you and your partner feel that you have reached the destination point, please let me know. You will have 30 minutes to complete this task."

Ask participants to start video recording and begin. Start researcher video camera and GPS recorder at the same time. Dyad navigates on foot the planned route. [30 min max]

- Dyad observed and video-recorded by researcher, who will **verbally note** times and approximate locations of activities, such as where the dyad stops or ventures off-route, mainly activities which help mark significant actions in the video or those not likely to be picked up on video.

- If dyad attempts (checks) 2 times at an incorrect destination point, tell them “You can try one more time to reach the destination.”
- If 3rd attempt is still incorrect OR if dyad reaches time limit of 30 minutes without having successfully reached the destination, stop recordings, then lead participants to either picnic tables or origin point (car) to complete Post-Navigation Survey. Make note on one of the maps that participants did NOT reach destination.

At end point, stop all video and GPS recordings. Lead participants to picnic tables near end point to individually complete Post-Navigation Survey. [approx. 5-10min]

- Instruct participants: “Now that you have completed the navigation task, I will ask you to individually fill out this survey based on your experience today.”
- Debriefing: “Thank you. Both of you have helped contribute to research on the understanding of how people work together to navigate. Here is the route the two of you took today during this navigation phase. [Show them on one of the maps. Explain the route they chose versus the shortest route, if interested.] Do you have questions about anything you did today as part of the research?”

Walk participants back to starting point and car, using path through open area. Drive participants back to campus. Thank participants, then give participation credit on the Research Pool system.

Materials

- online Pre-Study Questionnaire: http://geog.ucsb.edu/researchpool/participate/
- clipboard(s) with 2 copies each of printed materials:
  - Consent Form
  - Alternative (paper) copies of Pre-Study Questionnaire
  - Partner Familiarity
  - Site Familiarity (and zoomed-in map)
- For Phase I (Planning):
  - master copy of map of study site
  - video camera
  - 2 copies of maps for route sketches
- For Phase II (Navigation):
  - 2x GoPro Hero 3 video cameras for participants with chest mount
  - handheld Sony video camera for RA
  - cell phone with GPS tracking application “GeoTracker” (keep extra phone battery and Garmin GPS device as backup)
  - 2 copies of Post-Navigation Survey, clipboards, and pens

B.3 Forms and Questionnaires

See following pages.

Study Date/Time: ___________

Partner Familiarity

Since you will be working together in this study, I need to ask about your prior familiarity with one another.

First, how long have you known each other? _________ months / years

How well do you know each other?

Participant ID: ______
Participant Sex: _____

- ○ 1 = acquaintances, such as classmates or shared activities
- ○ 2 = occasionally spend time together outside of a class context
- ○ 3 = I would consider this person a friend
- ○ 4 = I would consider this person a best friend or romantic partner

Participant ID: ______
Participant Sex: _____

- ○ 1 = acquaintances, such as classmates or shared activities
- ○ 2 = occasionally spend time together outside of a class context
- ○ 3 = I would consider this person a friend
- ○ 4 = I would consider this person a best friend or romantic partner

Pre-Study Familiarity Questionnaire

Before your study begins, we require the following information.

Rate your familiarity with the following area labeled "Storke Ranch neighborhood" on the map, with the number 1 meaning "very unfamiliar" and 5 meaning "highly familiar".

Participant ID: ______

- ○ 1 = very unfamiliar
- ○ 2 = unfamiliar
- ○ 3 = somewhat familiar
- ○ 4 = familiar
- ○ 5 = highly familiar

Participant ID: ______

- ○ 1 = very unfamiliar
- ○ 2 = unfamiliar
- ○ 3 = somewhat familiar
- ○ 4 = familiar
- ○ 5 = highly familiar

Post-Navigation Survey

During navigation in the environment with your partner…

1. Did you and/or your partner take a path that was <u>different from your planned route</u> in any way? Describe if so.

2. Did anything <u>unexpected</u> happen (related to your navigation) while you and your partner were walking along your route? If so, what was unexpected?

3. Who acted more as the navigational <u>leader</u>? (circle one)
    a. I was leading more
    b. my partner was leading more
    c. neither was clearly leading more

4. Were there any points during which you <u>felt lost or unsure</u> about the route? If so, describe.

5. At any point did you and your partner <u>disagree</u> about the way to go? If so, describe.

6. Not considering how well you or your partner found the destination today, how <u>confident</u> are you in your partner's general sense of direction or navigation ability?
    a. very confident – I would never doubt their ability to find their way
    b. confident – I generally trust them to know where they're going
    c. average – I think they are about the same as most people in terms of navigation
    d. not confident – I would feel better if someone else were in charge of navigating

7. How long have you <u>known</u> your partner? (in months or years)

Appendix C

Social Interaction Analysis

C.1 Route Planning Transcripts

I follow basic conventions in Conversation Analysis, adapted from the guide by Sacks et al. [87]. This method of transcription attempts to directly capture speech as produced rather than along orthographic rules, aligns overlapping speech between two speakers [within brackets], uses colons to indicate the prolonging of a syllable, capitalizes louder speech, surrounds softer speech with °degree symbols°, and represents upward inflections with ˆ. Gestures are described within ((double brackets)). Pauses lasting less than a tenth of a second are represented as (.); longer pauses are shown with the duration in tenths of a second in parentheses.

C.1.1 Excerpt 1

```
A: what if we just go this way LOOK like right here ((tracing route on map)) (.) and then just like stra::ight there (0.5)
B: ((nods))
A: right? th- that's sp- what's gonna be (.) straightforward
B: yeah (.) what's this though (.)
```

C.1.2 Excerpt 2

```
A: I’m thinking maybe this way rather than that way thaway just seems
   longer tuh me (0.3)
B: oh yea:
A: um I dunno this way might actually be longer ((traces path with
   finger))
```

C.1.3 Excerpt 3

```
A: so: maybe we could go like up here, [and take]
B:                                     [nnye:ah ]
A: like a footpath (.) instead of walking all the way around
B: yea:h- but I also feel like what IS this in [the middle]
A:                                             [yeah^ I   ] have no idea
B: so I’m like WHAT is that (0.5)
A: so can it be like safer to like go through earlier? (0.3)
B: or like, go like this way and just cut throu:gh?
A: are we using this foot[path?]
B:                       [yeah:] [someth]in like-
A:                               [okay  ]
B: right here an:
A: are those houses?
B: I’m assuming ((laughter))
A: ss probably a fence or somethin
```

C.1.4 Excerpt 4

```
A: uh (.) if we’re dropped off here I feel like (.) the fastest route is
   like (.) obviously [this] because I dunno if we can cross right here
B:                    [yeah]
A: I don’t know if that’s water. [or a park or something ((laughter))]
B:                               [nnye:ah ((laughter))               ]
   (0.2)
A: UM we can always like just go alo:ng this road here (.) swee::twater
   way and then once we see coolbrook we can make a left
B: mmhm
A: that would be the easiest way
B: right at the [round]about, right, right-
   ((traces path with finger))
A:              [yeah ]
```

```
14 B: -right, and then coolbrook left
15 A: yeah
```

C.1.5 Excerpt 5

```
01 A: so mmm the safest way would be to go over around through [here]
02 B:                                                          [yeah] °true°
03    (1.2) or we could ↑also do this like this way
04 A: yeahh
05 B: that looks [longer:]
06 A:            [yeah   ] (3.0) hmm. (2.0) so
07 B: well these ARE like bike paths,
08 A: yeah so: we could [>walk on the side of the<]
09 B:                   [we could walk            ] on the bi↑ke path (4.0)
10    ((laughter))
11 A: then if really if theres nothing like thats right here that we find we
12     can just cut through
13 B: yeah (2.0) or like start here, use the road, >and then< use the b↑ike
14    path [and around]
15 A:      [ye:ah::   ]
```

C.2 Social Bookmarking Transcript

Dyad D29 [8:29 – 9:01]

```
01 A:   we here?
02      (1.1)
03      I think it is ((turns to face opening))
04      we went, around ((curves hand right))
05      (3.5)
06      ((leans over to look further down footpath))
07 B:   how d'you know when it sto^ps? (0.6)
08 A:   HUH? ((steps forward to look at exit))
09 B:   how d'you know when it sto^ps
10 A:   [>okay we'll just say it's here then<]
11 B:   [((turns away from partner))         ] (0.4)
12      no do we go^ through cause we're at-
13 A:   ((sweeps arm in big circle while looking at exit)) it's like-
14 B:   ((turns to stand next to partner, both looking at exit))
15      OH[H:::            ]
```

```
16 A:     [you know wha'I'm-]
17      so like cause we have to go off ((slides one hand across other))
18 B:   ??? [???        ]
19 A:       [go off of it] a lil bit (.) OR
20      (1.6)
21 B:   you thi^nk so? (0.3)
22 A:   cause we [went-  ] ((turns around and makes circle with finger))
23 B:            [wait I-] I feel like it is
24 A:   or should we just keep GOing ((points further down footpath))
25 B:   I unno (0.5)
26 A:   I think it's like somewhere he^re ((circles outstretched arm))
27      (1.2)
28      cause [it was like in between houses   ]
29 B:         [hey how bout we peek out and see] what's up over there
30      ((turns and walks through exit))
31 A:   ((follows partner))
```

C.3 Leadership Transcript

C.3.1 Excerpt 6

Example from Dyad 2 (03′06″ to 04′24″):

```
01 B: we were supposed to make a le-
02 A: LEFT, huh? a LE^FT? [wait (.) THA^T way?]
03 B:                     [that's why I said through the-] through the-
04    that's why I SAID I was like, through the THI^NG (0.1)
05 A: HH.h are you SU^RE?
06 B: NO I dunno^ ((shields eyes, looks in same direction as partner))
07 A: NO we go... ((turns, brings hands together)) kay on the map it was...
08 B: ((turns around to face same direction as partner)) (0.4)
09    ah.hh (0.1)
10 A: °out of° Sweetwater...
11 B: yeah Sweetwater ((turns to face same way as partner))
12    and then there was a LOOP ((draws circle with finger, points forward))
13 A: and then you go
14    [you go around the loop] ((extends left arm with right arm to elbow))
15 B: [then after you barely ] wa^lk
16    yea^h we go arou^nd the LOOP
... 28 lines removed for space considerations ...
```

A: cuz we were supposed to go a- (0.6)
B: NO cuz if you go through tha-
A: it's either we go-
it's either we go tha^t way ((points straight out with left arm))
or we come this way and we wait for the... ((holds out right arm)) (0.3)
no cuz we were [supposed t-]
B: [all right let's] just g- let's just-
let's just see, whatever (0.2) we'll just go through the streets
A: well, what- what are the pathways suppo-
[°walking pathways supposed to look like°]
B: [that's what I'm sayin like where are the p-] (0.8) pathway
(0.9) I don't know where the pathways were
(2.1)
A: I think they-
(0.5)
B: do you wanna go ba^ck?
A: Sweetwater... NO cuz if we woulda went tha^t way it woulda been
another stree::t

Appendix D

Study 3

D.1 Institutional Review Board (IRB) Consent Form

IRB Protocol from Study 2 modified to include Study 3. See B.1 for similar.

D.2 Protocol

See following pages.

Study 3 Protocol

1. Recruitment and Pre-Study Questionnaire

After participant is signed-up for a timeslot and at least 24 hours before timeslot, assign them a unique Participant ID (PID) and send link to online Pre-Study Questionnaire with PID by email.

Online questionnaire collects the following:

- Age of participant
- Sex of participant
- Familiarity rating with Goleta area
- Santa Barbara Sense of Direction (SBSOD)
- Big Five Inventory (BFI)

Send reminder email with meeting location and scheduled time the day before, and a reminder about the online questionnaire if they have not yet filled out the forms.

2. Meeting in the Geographic Cognition Lab [10 minutes]

Before participant arrives: Park car in closest legal space to the lab. Unlock and prepare lab area, set up video camera position (keeping OFF until Phase 1), and gather paper materials and pen for participant.

Once they arrive, greet participant and ask them to review / sign the Consent Form:
"This sheet explains the purpose and nature of this study. Please read through and sign at the bottom if you agree to participate. If you have questions about any part of this, let me know."

Assess familiarity with study site (Storke Ranch):
"First, I will ask how long you have lived in this area (Goleta / IV / Santa Barbara).
[Mark estimate on sheet.]
Now I will show you an area on this map which is the area we will be using for this study. [Indicate to participant on map.] This is a residential area called Storke Ranch, which is north of El Colegio Road and just east of Storke Road. It is located north of the Santa Catalina residence hall (FT). Please describe your prior familiarity with Storke Ranch."

- Write rating # for participant on Site Familiarity sheet
- Allow participation if 1 or 2 rating (you may need to use your best judgment about whether their prior knowledge is likely to affect their spatial knowledge of the area)

3. Phase 1: Prospective Planning [20 min]

Tell participants about video-recording: "Thank you. This planning part of the study will be video-recorded. This is only for analysis, not to be shared or posted online." [turn on and set-up camera above and far enough back to see participant's upper body and the map on the table]

At table in front room, instruct participant to plan route by themselves:
"Now, you will be working using a paper map to plan a route that you will have to walk in the next part of the study - without the map. While planning I will also ask you to talk out loud

about your planning process. Please talk as if you are thinking out loud to yourself and it will be recorded by the video camera. Working with the provided map only, please plan a pedestrian route to take between the marked origin ("O") and destination ("D") locations shown on the map [point to each on the map], minimizing as much as possible the distance and time to reach the destination. Make sure you remember your planned route, as you will *not be able to use this or any other map* when you walk through the environment in the next part of this study.

Again, while planning, please talk out loud to yourself about your thinking process. I encourage you to talk during the whole procedure as if you are thinking out loud. You won't get any verbal response or feedback from me, but please talk constantly at a normal volume until you are finished, at which point you may let me know you're ready."

- Sit at side table and observe planning – prompt participant again if not speaking
- Stop participant if they are still planning after 10 minutes (most won't need entire time)
- Stop video-recording

Collect <u>individual descriptions</u> of the route:
"In this next part, I will ask you about the route you planned. This will also be video-recorded."

- Start video recording to capture both you and the participant
- Instruct participant to <u>draw and verbally describe route</u>:
  "Now, on this map, please draw and describe in words the route that you have planned to take between the origin and the destination."

Ask <u>follow-up questions</u>, as part of the same video-recording as the individual descriptions:

1. "Did you consider any alternatives to this route?" (If yes: "Please describe and draw those routes on this map as well.")
2. "Are there any parts of the route or map environment that seem uncertain to you?"
3. "Do you think you would plan differently if travelling with a friend or partner? If so, how?"

This next phase leaves the lab and takes place in the actual study site. Tell the participant that we do not need to return to the lab room, but you will bring them back to campus (or nearby) afterwards. They should bring all their belongings with them.

<u>4. Phase 2: Situated Navigation</u> [10 min for travel, up to 30 min for navigation, 10 min for questionnaire and debriefing, 10 minutes to travel back]

Drive participant to study site (Storke Ranch). Park at or near origin as availability allows. Offer them the chance to leave belongings in car trunk if desired. Set up participant with chest-mounted video camera, then prepare researcher video camera and GPS tracker.

Instruct participant: "In this part of the study, you will follow your planned route between the origin and destination locations you previously saw on the map. You will wear a small video-camera and will also be video-recorded by the researcher as you navigate through the environment. You are not allowed to use your cell phone or another map to help you navigate, only what you remember and see in the environment. No need to follow the route exactly as planned before, but take the best possible route to reach the destination.
Again, please talk aloud about your thinking process while navigating. Speak at a normal volume, not to me, and this will be recorded by the video-camera. You do not need to

mention every thing that pops into your head, but anything that might be related to the navigation. You will not get any feedback from me, but please continue to talk constantly until you are finished.
When you feel that you have reached the destination point, please let me know. You will have 30 minutes to complete this task."

Ask participant to start video recording and begin. Start researcher video camera and GPS recorder at the same time. Participant navigates on foot the planned route. [30 min max]

- Participant observed and video-recorded by researcher, who will **verbally note** times and approximate locations of activities, such as where the participant stops or ventures off-route, mainly activities which help mark significant actions in the video or those not likely to be picked up on video.
- If participant attempts destination, confirm by asking: "Do you believe the destination point is where you're standing?" before telling them whether it is correct/incorrect
- If participant attempts (checks) 2 times at an incorrect destination point, tell them "You can try one more time to reach the destination."
- If 3rd attempt is still incorrect OR if participant reaches time limit of 30 minutes without having successfully reached the destination, stop recordings, then lead participants to either picnic tables or origin point (car) to complete Post-Navigation Survey. Make note on one of the maps that participant did NOT reach destination.

At end point, stop all video and GPS recordings. Lead participant to picnic tables near end point to complete Post-Navigation Survey. [approx. 5-10min]

- Instruct participant: "Now that you have completed the navigation task, I will ask you to individually fill out this survey based on your experience today."
- Debriefing: "Thank you. You have helped contribute to research on the understanding of how people work in real-world environments to plan a route and navigate. Here is the route you took today during this navigation phase. [Show them on one of the maps. Explain the route they chose versus the shortest route, if interested.] Do you have questions about anything you did today as part of the research?"

Walk participants back to starting point and car, using path through open area. Drive participants back to campus. Thank participants, then give participation credit on the Research Pool system.

Materials

- online Pre-Study Questionnaire: http://geog.ucsb.edu/researchpool/participate/
- clipboard(s) with copies of each of printed materials:
  - Consent Form
  - in case of NOT filling out Pre-Study Questionnaire online:
    - SBSOD scale
    - Big Five personality inventory
  - Site Familiarity (and overview map)
- For Phase I (Planning):
  - master copy of map of study site
  - video camera
  - map for route sketches
- For Phase II (Navigation):

- 1 GoPro Hero (2014) video camera for participant with chest mount and charged batteries
- handheld video camera for RA
- cell phone with GPS app “GeoTracker” (keep backup charger / battery)
- Post-Navigation Survey and pens

D.3 Forms and Questionnaires

See following pages.

Study Date/Time: ___________

Pre-Study Familiarity Questionnaire

For this study, I first need to ask about your prior familiarity with the area.

First, how long have you lived in Goleta / Santa Barbara? _________ months / years

Rate your familiarity with the following area labeled "Storke Ranch neighborhood" on the map, with the number 1 meaning "very unfamiliar" and 5 meaning "highly familiar".

Participant ID: ______

- ○ 1 = very unfamiliar
- ○ 2 = unfamiliar
- ○ 3 = somewhat familiar
- ○ 4 = familiar
- ○ 5 = highly familiar

Post-Navigation Survey

During navigation in the environment…

1. Did you take a path that was <u>different from your planned route</u> in any way? Describe if so.

2. What was your main <u>strategy for remembering</u> your route plan during the navigation in the neighborhood today?

3. Did you have specific <u>cues or landmarks</u> you were looking for during navigation?

4. Did anything <u>unexpected</u> happen (related to your navigation) while you were walking along your route?
   If so, what was unexpected?

5. Were there any points during which you <u>felt lost or unsure</u> about the route or which way to go?
   If so, describe.

6. Not considering how well you found the destination today, how <u>confident</u> are you in your general sense of direction or navigation ability?

   a. very confident – I would never doubt my ability to find my way
   b. confident – I generally trust myself to know where I'm going
   c. average – I think I am about the same as most people in terms of navigation
   d. not confident – I would feel better if someone else were in charge of navigating

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