Getting "There" from the Ever-Changing "Here"
Following Digital Directions

Ranjit Singh, Chris Hesselbein, Jessica Price, and Michael Lynch

> *Having just come out of a jungle, I can't promise you that in leading you in to show you what I've found that I won't lose the way for all of us.*
>
> **—Garfinkel (2008, 101)**

"Lost" in the Ever-Changing "Here"

The research for this chapter began with an exercise for a seminar on visualization in science and technology studies (STS), and each of the authors performed variations of it.[1] The exercise was designed to bring into relief the situated practices of following rules, plans, and other formal instructions.[2] Such practices can be subsumed under a theme that ethnomethodologist Harold Garfinkel dubbed "instructed actions" (2002, 197–218), a theme that also became a fixture in STS and information studies largely through the influence of Harry Collins's investigations of the tacit knowledge involved in efforts to replicate scientific methods and instruments (1974, 1975) and Lucy Suchman's research on the situated actions of enacting technical protocols in workplaces ([1987] 2007).[3]

The exercise we discuss was designed to explore the emergent contingencies, practical problems, and repairs that arise during efforts to follow different versions of maps and directions in the course of particular journeys. A number of variations were possible, depending upon the kind of "map" used: a standard printed map, a line or two of written directions, a hand-drawn "occasion map" that directs the user to a particular address or place, or a GPS (Global Positioning System) device. Before, during, and after our journeys, we took detailed notes about what happened along the way. We paid attention to the particular map-reading practices, and took notes on how maps informed and confused our wayfinding. We also took notes on the difficulties and contingencies we encountered and how we contended with them. In our notes and discussions we paid special attention to what is distinctive about different kinds of maps and directions, as visual/textual devices for organizing practical actions.

In addition to performing one or another variant of the exercise, we read selections on the design of maps and their epistemic and practical implications (Brown and Laurier 2005; Vertesi 2008; November et al. 2010).[4] We wrote up brief reports on the exercises, often focusing on wayfinding difficulties and experiences of being lost. A low-tech example will help set the stage for identifying themes that arose in the GPS-aided examples to follow. In this instance, one of us attempted to use instructions written by a friend on how to get from a residence in Brooklyn to a museum in Manhattan. The field notes begin with a quote from the directions:

> "Exit at 77th. Met is the big white building at 82nd and 5th Avenue."
>
> It was my first time in New York City. I alighted the 6 at 77th and walked up the subway steps into the street. The sidewalk was crammed with people, the buildings were tall, and I could hear yellow taxicabs honking at each other. It was exactly what I had hoped Manhattan would be like and I was delighted. Sadly, this initial rush gave way to a less pleasant feeling: I realized I was lost.
>
> Until I exited at 77th I had successfully followed my friend's written instructions. Entering the subway in Brooklyn I had changed at Union Square and taken the 6 to the Upper East Side without any problems. Allegedly, I had prepared myself for this part of the journey by looking at an online map of the area. In my mind it had all seemed so simple. The museum was only a few blocks across, then a few blocks up. The problem in that moment outside the subway steps on 77th was that I didn't know which direction was across and which was up. I grew up in Great Britain, which doesn't have any grid systems and it hadn't occurred to me that I might find the layout of Manhattan, in so many ways so logical, so utterly discombobulating. I looked around trying to overlay the map I had in my head of the route against what I could see in front of me and just kept failing. I decided that my chance of going the correct way to the park was 50% and that it would be worth walking a few blocks to see whether I could get there without having to ask for directions. Knowing Central Park was a large tourist attraction, I judged the direction most people were going and followed the crowd. My gamble paid off and once I had arrived at the park I was able to see the museum, according to my written instructions, "the big white building," very easily.

Even in this case, online resources came into play, as the written instructions were supplemented by consulting online maps for the layout of subway lines and their identification with street numbers, and these directional resources were crucial for coordinating instructions with the signs and directional indicators placed in subway stations and on street corners. And yet, our navigator still found that she was *lost* after exiting the subway stop, as the spatial direction "up" on a map had no clear correlation with her immediate embodied experience of the cityscape. After finding herself lost, our navigator improvised by reading the legible infrastructure of the city, and following pedestrian traffic flow until the description of the destination *came true* in immediate experience. We shall return to these themes of improvisation, and the coordination of various instructions with the legibility provided by the local infrastructure. But first we shall discuss how the exercise critically relates to navigational tools, especially the GPS.

We became intrigued by the GPS because, unlike a map or a set of written or verbal directions given prior to a journey, it adapts its instructions during the journey. Accordingly, the apparent gap between formal instructions and situated actions

collapses. However, as we shall see, the GPS turns out to be less of an earth-shattering, paradigm-shifting device than it seemed at first glance, and its use requires some older and trusted forms of supplementation and repair. Specifically, as suggested by the above vignette about navigating in Manhattan, various backup systems and legible environments often supplement or override what initial instructions show and tell us to do. Although the GPS continually adapts to our position as we go along, the salience and authority of its directions can be, and frequently are, overridden.

Before turning to our exercises with the GPS, we shall discuss specific modalities of tacit knowledge that are tied to different sets of navigational instruction. We focus on the experience of "being lost" because, however disconcerting it can be at the time, it is an excellent "tool" for gaining insight into wayfinding practices. Our chapter draws upon numerous instances of journeys performed by the authors with different forms of maps and directions in different situations, but the focal point will be a series of exercises involving navigation through familiar and unfamiliar terrain using GPS directions. Therefore, after engaging with the literature, we will provide insight into how the relationship between maps and journeys is reconfigured with the use of digital media. In the spirit of the present book, we also encourage readers to perform similar observational exercises.

Ways of Getting from A to B

The wayfinding exercise provided a simple way to explore the limits of rational action. A journey from point A to point B is a prototype of rational action, in the classic sense in which an actor in a situation selects an efficient means for achieving an end.[5] Point B is the "end" while point A is the origin or starting point of such an ideal-typical act, and the act is performed under the jurisdiction of an aim to reach the end with minimal difficulty. In this case the "actor" is what Goffman (1972) defines as vehicular unit: "a shell of some kind controlled (usually from within) by a human pilot or navigator." This definition can be expanded beyond mechanical vehicles to include pedestrians navigating with their bodies (though the Cartesian "ghost in the machine" implications are disconcerting, and we wouldn't want to assume that the navigator simply parks the body and walks away at the end of the journey). Importantly, for Goffman, the navigator's choice of means (direction, path, available type of vehicular unit, etc.) is deeply attentive to moral, social, and physical barriers, rather than being an exercise in what we could call "Euclidean geography." Among other things, it is enabled and constrained by a *traffic code*: "a set of rules whose maintenance allows vehicular units independent use of a set of thoroughfares for the purpose of moving from one point to another" (6). Accordingly, the route taken as a means to the end follows standardized and normative (socially available and positively sanctioned) pathways.

As a sociologist, Goffman emphasizes traffic *rules* that prohibit what Robert Merton (1938) once called "innovative" actions: actions that pursue normatively approved ends by means that transgress legalities and social conventions. Imagine an idealized Euclidean navigator, attempting to follow the most direct geometrical path from A to B—a straight line drawn on a map—which would require cutting across streets, climbing over fences and scaling walls, trespassing on private property, and walking through gardens and homes.[6] Aside from encountering formidable physical barriers and hazards, such an actor would very likely provoke an

extreme social and legal reaction about as quickly as if she or he were walking naked in public.[7] When walking from A to B, we normally do not even think about such possibilities, though when driving we occasionally do, for example, go against a directional arrow to enter a parking lot at its exit; or, more rarely, quickly cut across a divider strip or scoot for a short distance the wrong way up a one-way street. And we may do so by mistake. In brief, when points A and B are established as origin and destination, the rational actor does not choose the shortest distance between the two points. However, the traffic code and related rules are far from the only barriers the deter our traveler from navigating along an ideal geometrical pathway: rules are materialized, supplemented, and occasioned by traffic lights, pedestrian crossings, warning signs, and entrenched roadways. Rules and their rationalities are emplotted and inscribed into the territory, and the very surface of the terrain is underlaid by and overlaid with "mundane artifacts" (Latour 1992), making up a complex infrastructure of steel-reinforced concrete pathways that guide and block the movement of vehicular units.

Our wayfinding exercise was not designed to illustrate a conception of rational action with empirical examples; instead, it was designed to *make trouble* (Garfinkel 1967, 37) for any such conception by exposing the potential complexities and contingencies that arise in relation to whatever counts (or not) as an optimal path from A to B.[8] Instances of such trouble would then provide leverage for opening up discussion of what is missing *both* from particular forms of instruction *and* from theories of rational action. In a critical discussion of "plans as programs," Phil Agre and David Chapman suggest a different conception of plans as communications in which actions are a matter of "following natural language instructions" where "the agent uses the plan as one resource among others in continually redeciding what to do. Using a plan requires figuring out how to make it relevant to the situation at hand . . . as participating in the world, not as controlling it" (Agre and Chapman 1990, 17). Consequently, an existing plan may be revised or aborted in light of the unique contingencies and opportunities that arise in a specific course of action. This conception of navigation is related to the resilient theme of *tacit knowledge*.

Tacit Knowledge

The theme of tacit knowledge has a long association with STS and the information sciences, dating back to Michael Polanyi's (1958) philosophical writings on scientific practice, and Hubert Dreyfus's (1979) critique of artificial intelligence. Tacit knowledge covers an array of phenomena, including embodied skills acquired through practice, covert understandings shared among members of a guild or profession, and ubiquitous ways of acting acquired through participation in a society (see Collins 2010 for a classification of domains of tacit knowledge). Tacit knowledge is one of a family of terms such as know-how, knack, *Fingerspitzenfühl*, improvisation, tinkering, and bricolage—all of which reference the practical judgment, interpretive flexibility, situated action, and embodied dexterity required for performing skilled work. One common way to highlight the role of tacit knowledge in the natural sciences, which became important for establishing STS as a field, was to point to a *gap* between formal accounts of scientific method and close observations of scientific and technical practices. Well before STS became established, Peter Medawar asked in the title of a popular magazine article, "Is the scientific paper fraudulent?" He answered in the subtitle, "Yes; it misrepresents scientific thought"

(1964). Medawar went on to explain that the charge of fraud was an exaggeration, and that what he was suggesting was that scientific papers provide systematically misleading narratives of scientific "thought" (and, as later work in STS documented, "thought" was a thin way of describing the complex assemblages of embodied work, technological virtuosity, craft, artistry, and routine interaction that compose scientific practices). Not only were such reports misleading as post facto accounts of scientific work, they also were virtually useless as sources of instruction on how to perform and replicate such work. This gap between formal, written prescriptions and the actual performance of technical actions also framed Michael Polanyi's writings about tacit knowledge—the embodied skills and know-how learned on the job through experience and apprenticeship, rather than through formal instruction: "Textbooks of diagnostics teach the medical student the several symptoms of different diseases, but this knowledge is useless, unless the student has learnt to apply it at the bedside. The identification of a species to which an animal or plant belongs, resembles the task of diagnosing a disease; it too can be learnt only by practicing under a teacher's guidance. . . . Thus, both the medical diagnostician and the taxonomist acquire much diagnostic knowledge that they could not learn from books" (Polanyi 1962, 603). Textbook instructions not only are written but also attempt to formulate abstract accounts of activity that specify what practitioners must do under highly variable conditions, and while such instructions might give helpful guidance for novices, they cannot possibly encompass any and every single episode. Empirical STS research, starting in the 1970s, addressed a gap between, on the one hand, formal accounts of practice and, on the other, the embodied and mechanical performance of practices in particular situations (Collins 1974, 1975; Suchman [1987] 2007; Garfinkel 2002). The critical import of the gap between formal instructions and practices also applied to technological efforts to incorporate human actions into "instructions" programmed into a computer.

It is tempting to think of tacit knowledge in terms of a dichotomy between a formal (written, programmed, decontextualized) part and an informal (situated, enacted, contextual) part, and to develop a critique of the formal part by elaborating upon its failure to specify the embodied practices and skills necessary to perform the informal part in particular circumstances. However, instructions conveyed by word of mouth, written recipe, nonverbal diagrammatic sequence, video demonstration, and interactive exchange are not all of a piece, and many of them incorporate or reconfigure activities that might otherwise be assigned to the "tacit" (systematically hidden, informal, situationally specific) side of the ledger. This lack of strict demarcation provides hope for behavioral engineers who suppose that mechanisms discovered by cognitive neuroscience and/or built into sophisticated programs will eventually encompass even the most recalcitrant aspects of human and nonhuman actions. Hubert Dreyfus (1992, 100) once remarked that such hopes are akin to an attempt to build a ladder from the earth to the moon—it is always possible to add another rung, but the project as a whole will literally never get off the ground. Whether or not Dreyfus was right about this is not germane to our interest in this chapter. Instead, the reconfiguration of tacit knowledge with different communicative devices itself calls for investigation (Lynch 2013). Without specifying a fixed point at which formal directions leave off and tacit knowledge takes over, we begin with the idea that the relations between instructed actions and tacit knowledge continually change, not only with the situations in which

instructions are applied, but also with particular technologies through which instructions are embodied and conveyed. Consequently, for any existing device that somehow instructs or guides a journey, there will be an investigable domain of tacit knowledge in relation to *that* device and its uses.

Maps and Their Gaps

Directions, maps, and navigational devices are instructional technologies:[9] they do not simply convey information in accordance with standard designs. When used for a particular journey, these technologies convey navigational directions. They are materially, semiotically, and narratively configured, and their configuration is tied to their use in specific environments. Like other tools, they exhibit transparency or transitivity. Polanyi used the example of a stick or probe that a blind person uses to navigate, suggesting that the instrument user "dwells" within the instrument. It is as though the instrument becomes an extension of the body, as the person "feels" the texture of the sidewalk touched by the end of the probe, and the sidewalk acquires distinctive properties tied to the probe (as well as the soles of shoes) through which it is "felt" (also see Merleau-Ponty 1962). This also applies to directions and maps, as the landscape acquires properties in relation to their communicative interface. Written or spoken directions typically begin with a point of origin and end with a destination, while including reference points to what "you" should look for, and where "you" should turn (or turn back, if "you" have missed a turn) during the journey. These reference points embed "phenomenal field properties" (Garfinkel and Livingston 2010) within the material/semiotic form of the directions, implying a phenomenological situation *in the world* within an objectified account of a landscape. Google Earth and GPS navigational aids embed further phenomenal properties into a more dynamic and circumstantial display of the immediate field of action (November et al. 2010).

Drivers, walkers, and ocean navigators have access to an array of formal navigational devices, and the practices of using them have been studied for decades by anthropologists, ethnomethodologists, and communication scholars. Commonplace devices used for driving or walking along streets and thoroughfares range from mass-produced and standardized tools to specific ones tailored for a particular journey:

1. **Comprehensive maps**. A comprehensive map is designed to be used for an open-ended array of purposes. There are, of course, many different varieties of comprehensive map, and in this chapter we discuss only road and street maps designed to guide wayfinders within and through the mapped territory. There also are many varieties of these, varying in scale and resolution, and deploying different conventions and orientations (e.g., for tourists, marking sites of special interest, scenic routes, etc.). The design of such maps is suitable for a range of specific purposes, but they do not include singular points of origin and destination, though a particular route can be inscribed by hand on them prior to a journey.[10] Trouble can occur during a journey when you presume to be "on" the map at a moment when you are actually "off" of it, or when you presume to be "off" the map and you are "on" it, or when you think you are "on" the map in one place, but you are actually "on" it in another place.

2. **Placed maps.** These are "immutable *im*mobiles" that are fixed in place, and preserved against the elements.[11] As noted above, they can be found on campuses, in city centers, and at highway rest stops. Typically, they are standardized maps, of "appropriate" scale, which may be identical in many respects to portable road and city maps distributed by a tourist office or found on a campus website. Typically, they include a "you are here" mark (for discussion of such placed maps, see Latour 1987, 162; Laurier et al. 2016), and they may include special features of interest to tourists or visitors to a campus. In this case, the fixed locale of the map enables its virtual-phenomenological "here" to be inscribed. It is a peculiar "here" that usually leaves unspecified where else "you" might go from "here," though it might provide helpful indications of where and how "you" *might* reach any of an indefinite number of different destinations via available roads, underground lines, or walking routes.
3. **Verbal directions**. These are delivered orally and/or in writing and denote a linear sequence with conditional features. George Psathas (1990, 183) likens them to "stories," because the sequential organization of their telling narrates a temporal progression. This analogy links the Christian/Western notion of *telos* in storytelling to the way in which navigation involves moving from "here" to "there." The directions are ordered not only as a story, but also as a series of commands for a series of actions to be taken. Conventional sequential features include such instructions as "Take Route 17 East to Binghamton, and several miles past Binghamton, take US Rt. 81 South." Of course, the story is highly compressed, and the journey will include long intervals between directions, sometimes denoted by distance, time, or other measures ("after turning left, go five blocks"; "stay on 81 for around 20 miles, until . . ."; "in five minutes or so, you should see . . ."). Conditional features often are included in instructions, such as, "if you pass under a railroad bridge, you've missed the turn." There is a significant difference between written and oral instructions, as the written instructions can repeatedly be consulted, while the oral instructions are subject to the vagaries of recall.
4. **Occasion maps.** Like verbal directions, and often combined with them, these maps are drawn for a particular occasion and typically discarded afterward, though in some cases they may be retained and reused on other occasions. Psathas (1979, 204) observes that these maps are non-topographical, in the sense that they do not include standard coordinates and scales, and provide little or no mapping of terrain beyond the linear route to be taken.[12] Consequently, it is easy to get "off" the map and hard to find one's way back "on" to it. Written directions often include a variable amount of sketched detail, and more elaborate sketch maps typically include written directions and labels. Occasion maps typically include a starting point and destination (which can be reversed for a return journey), lines for routes, denotation of cross streets, traffic lights, names for key streets, and landmarks, and a few other features. Although occasion maps are drawn for a specific journey, there is no less of a "gap" between their features and those that arise in the course of a journey than there is for standardized road maps (Liberman 2013).
5. **Navigational instruments**. This category is worth exploring further, though we shall not do so here, except in the case of GPS. Historically, navigational instruments (sextant, compass, etc.) were crucial for reckoning direction and distance. In an automobile, the most commonplace navigational instru-

ments are the speedometer and odometer, and less commonly a compass. A built-in or portable clock or wristwatch also may be included among the instruments. Increasingly, digital aids are built into the vehicle, including GPS.

6. **GPS**. There is a rapidly proliferating variety of GPS and related navigational tools. A GPS is, in a sense, a navigational Turing machine,[13] in that it combines and affords variable combinations of maps, directions, and instruments. It can be adjusted to simulate voiced directions, inscribed directions, road maps, or placed maps. It also can simulate a vantage point akin to that of a driver or passenger viewing an unfolding road scene, but it's "here" differs from the scene available through the windshield. When fixed to the windshield, a GPS is a second, miniaturized window that delivers a distinctively organized vantage point from a virtual position "above" a schematized version of the vehicle and the space surrounding it that is more characteristic of a map than the phenomenal field of driving. Using it while driving is a matter of seeing double. In the case of walking with a smartphone, the schematic virtual window differs from the environment that surrounds the walker.[14] In the instances of driving described in this chapter, a Garmin device attached by suction cup to the windshield was used; in cases of walking, the navigation was with Google Maps on a smartphone.

A Turn-Taking Machine

The GPS does more than incorporate and combine aspects of road maps, placed maps, occasion maps, navigational instruments, and verbal directions. The most notable features are its voice, which all too literally (mis)pronounces street names while giving instructions about upcoming maneuvers, and displaying a continually updated, forward-looking street map that shows where "you" are at any point in the journey. The voicing of directions is akin to a companion with a limited repertoire consisting mainly of turn-by-turn instructions, such as "In about a quarter of a mile take a left exit onto University Avenue" (Brown and Laurier 2012, 1623). These instructions are organized differently from the turn-taking machinery of conversation (Sacks et al. 1974); instead of being tied to the speaking turns and turn-transition-relevance places of an ongoing conversation, they are programmed in relation to upcoming intersections at which turns should be taken or not in the course of the journey. Although drivers and passengers may respond to the voice, talk around it, yell insults at it, or shut it off, the order of the GPS's turns is more akin to a list of commands, not unlike verbal directions, except that the directions are adjusted and are recalibrated to the position of the vehicle on its path toward a programmed destination. In this way, following the GPS is akin to what Psathas (1986) and other ethnomethodologists (Psathas and Kozloff 1976; Garfinkel 2002, 179) describe in their studies of verbal direction giving and direction following.

Wayfinding Troubles and Repairs

As noted earlier, instructed action exercises are designed to elicit troubles—troubles that disrupt the transition from formal instructions to particular efforts to enact them. Such troubles have methodological significance as "aids to a

sluggish imagination" (Garfinkel 1967, 38), as they allow for both critical attention to the limits of preset plans or programs of action, and articulation of how tacit knowledge or situated action comes into play in specific cases and domains of action. And, as we shall argue, such exercises encourage us to reconsider what we might possibly mean when we use catchall categories such as "tacit knowledge."

Wayfinding troubles often occur during efforts to bridge the "gap" between a plan for a route composed in advance and an ongoing journey that attempts to follow the plan. This gap might be said to arise from what Tim Ingold calls a "paradox at the heart of modern cartography": "The more it aims to furnish a precise and comprehensive representation of reality, the less true to life this representation appears" (2000, 242). The immobility of inscribed detail in maps (of any kind), so suitable for reproduction and dissemination (Latour 1990), contrasts with the mobile vantage point of the journey. Because of the emergent, site-specific, and idiosyncratic contingencies arising in the course of unique journeys, there is no possible way for a map to include enough detail to anticipate such contingencies. However, with a GPS one might suppose that Ingold's paradox is dissolved, as the gap between map and journey closes up, even though it never quite disappears. This is because the GPS continually updates its instructions, adjusting to changes in location and recalibrating the route when the vehicle goes off course, takes a side journey, or heads to a new destination. Although the GPS receives digital signals from a satellite or an array of cell phone towers and computes geographical coordinates, it translates these coordinates into a simulation of a mobile existential "here" rather than a static objective location.

However, while the GPS may seem to close up the gap between instructions and situations of action, it opens up another gap between the display on its screen and a more encompassing scene in which the screen is embedded.[15] The screen displays a small schematic field organized around "here and now" incorporated within the vehicular unit's *umwelt*: a field of action and instrumentation with its own "here and now" that extends from the vehicle dashboard, through the windshield and mirrors, reaching into the terrain along the line of vehicular movement. The practical alignment of the two fields is a task and occasional source of trouble for navigation (Brown and Laurier 2012). Various kinds of trouble arise when using a GPS, especially for novice users but also for others who have more practice with the device. In what follows, we focus upon an array of troubles and repair efforts arising from (apparent) misalignments between the field accessed through the GPS interface and the more encompassing environment of its immediate use.[16] Repairs in these instances are not a matter of fixing a faulty device but a matter of contending with momentary troubles that arise through "normal" interactions between the device and its user. Some of these troubles may be eased or eliminated through future improvements in the devices and their programming, but many are endemic to following directions. Repair is less a matter of fixing technology than of improvising ways to use it in particular situations—of relying upon as well as further developing what Sawyer et al. (this volume) call "infrastructural competence." As Jackson (2014, 226) points out, repair involves innovative work, though often of a kind that receives little notice.[17]

Two different situations were used in this study to explore the relationship between the GPS and the environment. One situation involved using a GPS to navigate from A to B in familiar environments (e.g., using the GPS while walking or driving from office to home), while the other involved using the GPS as a resource

to guide journeys through unknown (or vaguely known) territory. Performing the exercise alerted us to the ambiguity of this distinction, as it challenged us to reconsider what it means to *know* where you are and how to get to somewhere else. When we performed these exercises (or when we described experiences that were not originally planned as exercises), the distinction between familiar and unfamiliar destinations became complicated.

Using GPS in Familiar Environments

When a GPS was used as a guide, familiar environments acquired elements of unfamiliarity, and following the GPS directions also created awkward interactional situations. One of us used a GPS program on a smartphone to guide a walk of approximately two miles from a campus location to home. As happened in most instances in which we attempted this variant of the exercise, the route suggested by the GPS differed from the "usual" route.

> As I walked on this route, my first observation was that interacting with the visual interface of the GPS and the sense of continuity that it offered [in comparison to sporadic consultation of a static map or written directions] had considerable impact on my awareness of the environment. My focus shifted from the roads and crossings to the visual interface of the GPS and its pointer indicating where to go next, which was continuously updated as I went along. I was walking with a friend who knew the route as well as I did, and our conversations became sparse as my focus was continuously on the GPS interface. This lack of communication became an issue as the exercise progressed, because I had not informed my friend in advance about this exercise. Ultimately, I had to change my performance of the exercise to some extent to preserve the texture of the everyday ritual of walking back home from campus.

At first, the companion on the walk did not take issue with the use of the phone, since walking while fixated to the screen of a phone is far from uncommon these days, but when the path guided by the phone diverged from the usual route, the companion began to raise questions:

> Dryden Road has a curve situated between Aladdin's Natural Eatery and Sangam Indian Cuisine. A staircase allows you to cut across the curve and is a known shortcut. While some of the stairways that can be taken as shortcuts are listed on Google Maps, this one is not recorded. Again as I tried to follow the curve (*absent-mindedly looking at the GPS interface on my phone*), my friend finally asked me what I was up to with my phone and why was I deviating from the normal route that we usually take. I explained to him the objective of my exercise and he suggested an alternative to continuously looking at the interface while I walk.
>
> Friend: Increase the volume of your phone, so that you can hear the instructions of the GPS, and then you can avoid having to look at the interface continuously!
> Me: Should we follow the instructions together?
> Friend: No, we can also just look at where the GPS route deviates from the route that we usually take.

Following the companion's advice led to a significant change in the exercise: instead of following the GPS instructions blindly, largely oblivious to the surroundings and the familiar routes through them, the two walkers treated the GPS directions as an option. When they ignored the GPS directions it recalibrated its instructions, and when they ignored the new instructions it recalibrated them again. The GPS consequently *followed* rather than *led* the route taken by adapting its directions continually with each divergence from its prior directions. This change in procedure opened up questions concerning "hardness" of instructions and also the relationship of dependency between human and machine. While some instructions are "hard" in the sense that if they are not followed correctly, the end result will be disastrous, not following GPS instructions in this case turned out to be easy and inconsequential for the ultimate success of the journey.[18] The *gap* (or, rather, series of gaps) between the instructions and the situated actions became gratuitous and was repeatedly ignored.

Being Lost with the GPS in a Familiar(?) Environment

On some occasions, following the directions given by the GPS led to being lost. There is something paradoxical about being lost with a GPS, since a major reason for using the instrument is to *avoid* getting lost. Moreover, a GPS system specifies with great accuracy where exactly you are on its map, even when you have no idea of where that is. However, from our experiences with using the GPS, both in specifically designed exercises for this project and in everyday use, getting lost with a GPS was far from uncommon. Though disconcerting at the time, such occasions provide some insight into what it means to *be* lost as an existential experience—a way of (not) being in the world; and, as Ingold (2000, 219) observes, being lost also allows for reflection on "what it actually *means* to know where one is, or the way to go." When it is functioning correctly (getting a signal and displaying it on the screen), a GPS should provide the user with a precisely located moving position on a map and a schematic display of local surroundings, as well as other verbal and numerical information about street names, intersections, and the distance and time to destination. However, experiences with getting lost involve a kind of double vision where the "view" provided by the instructions gets out of alignment with the other view of "where you are" provided by the vehicular *Umwelt*.

With verbal directions, an occasion map, or even a local road map, you may find (or suspect) that you are no longer "on" the described route, or even on the map, and finding your way back to the route and/or map (or otherwise finding your way to your destination) can become quite difficult as you search for landmarks—singular features that render the landscape *legible* (Lynch 1960). You may also find (or suspect) that you are still "on" a road map or topographic map, but are no longer where you previously thought you were. The immediate environment may provide few if any clues. For hikers lost in a desert landscape, the plants, sandy washes, rock formations, and horizons may seem indistinguishable from those found at any other locale for miles around. For drivers in another kind of desert—a seemingly endless series of franchised fast-food restaurants, gas stations, and strip malls—the landscape provides no clue about "where you are," even though everything in the surroundings seems all too familiar. With a GPS, however, even if you deliberately or inadvertently abandon the original route from A to B and have no idea of where you are, the device *should* provide you with a continuous dis-

play of where you are on a map, and it *should* instruct you on how to get to your destination from there. Sometimes, however, the GPS fails, or the user fails to program or follow it correctly (these two possibilities often are indistinguishable in the course of a journey).

When we performed the exercise, instances of getting lost with a GPS were not clear-cut. In many instances, it dawned on us gradually that we were lost, and we were never entirely sure that if we kept following the route the GPS prescribed, it would get us to our destination more quickly than if we abandoned that route. The following description of trouble that occurred during a drive from Ithaca to Boston is one of several cases in which we used the GPS in more or less familiar territory—*more or less* familiar because the GPS tended to "discover" routes that the user had not previously taken or even imagined.

> I hadn't used the GPS in several weeks, and it didn't set up too quickly or easily when I entered the destination address. At one point after we set out, it seemed to be showing where we were after a time delay of a minute or so, but we knew where we were, and could ignore it. Eventually, it seemed to catch up with us. As we drove through Whitney Point, went on Route 26 S., and headed toward the onramp for I-81 South, the GPS instructed us to go straight on Route 26 past the onramp, and I decided to go along with it on the chance that it "knew" a shortcut. As we followed the designated route, it became increasingly clear that we were not going a good way. Rt. 26 goes to Endicott, several miles west and south of where we would pick up I-88. And, it goes through several small towns. There didn't seem to be a good way to backtrack or to improvise another route, so we stayed with the GPS, and lost at least a half-hour of travel time. Eventually, we pulled the plug of the GPS from the cigarette lighter, and then re-inserted it, and after setting it up again it seemed to behave itself, and our trip was uneventful from there until we hit Boston.

When reflecting on events like this, we are left with questions about whether to blame the device for absurd directions or to acknowledge the possibility that we set up the trip wrong and/or misread the directions. Like other digital devices, the GPS does not provide transparent indications of some of the settings, and either you have to remember how it is set it up or consult the manual, both of which are difficult to do on the fly. One particularly annoying possibility is that the GPS may inadvertently have been set for surface roads, to avoid freeways, or set for the shortest distance rather than quickest journey, and the particular settings are not easy to find or change, especially when the journey is under way. Even if we take the blame for incompetence, our failures point to the requirement for distinct competences with following GPS instructions, and also anticipating such instructions, setting up the device correctly, and knowing when to disregard the GPS.

In this instance, the driver already knew how to get from A to B. But unlike in the prior example of using a GPS on a walk through familiar territory, there were junctions at which trust (or hope) invested in the GPS directions overrode the driver's sense of the best route to take. This relates to a point that Leshed et al. (2008) make that the GPS can alienate the user from the environment by offering an unquestioned source for the user to follow instructions blindly. Accordingly, while easing the burden of reading the landscape in an unfamiliar territory, the GPS obviates the necessity of taking note of the environment. When it dawns on us that the GPS is leading us astray, a dilemma begins to take shape: should we stay with the device

in hopes that it "knows" the route better than we *thought* we did, or should we privilege our own judgment and abandon it? A variant of this dilemma is more playful and leisurely: should we follow the GPS to see if it will find a novel way to get to where we know we are going, or should we abandon such curiosity and revert to our habitual route? The possibility of abandoning reliance on the GPS, and relying upon other navigational resources, including, when available, our own familiarity, points to options and even forms of play that counteract the tendency to invest unquestioning trust in the machine.

Getting Off the Beaten Track: "Here Be Dogs"

When discussing their conception of plans as communicative resources rather than as self-sufficient programs that drive action, Agre and Chapman (1990, 17) observe that "the agent uses the plan as one resource among others in continually redeciding what to do." Although a GPS itself performs a calculative version of such "redeciding," effectively using this tool also requires treating it as one resource among others. Experiences of being lost with the GPS provide clear reminders of that necessity, and they also provide analytical insight into the alternative sources of directional instruction that may be at hand or found in the environment. A vivid example of how such backup systems can come into play occurred during the performance of the exercise in San Juan, Costa Rica.

> This trip occurred during a vacation, and involved a driver (me) with a rental car, and a local guide who did not drive but supplied a windshield-mounted GPS programmed for our destination. I spent a fair amount of time in the days before the trip reviewing and rehearsing with online resources how to get to the destination . . . a national park around 90 kilometers from the city. On the appointed morning, we set out confidently.[19] The initial problem was to get from the hotel to the Pan American Highway, which would take us to the national park. The guide was unfamiliar with the neighborhood around the hotel, and so we relied on the GPS to get us to the highway and out of the city. This is when the trouble began. At the start, the guide turned off the GPS "voice" because he could not tolerate the way it pronounced Spanish street names, but the visual display gave us clear directions and the lack of the voiced directions was not germane to the problems we encountered. Not long after we started driving, we became increasingly uneasy as the GPS led us through numerous local roads at the outskirts of the city, with no main highway in sight. We stayed with the directions in hope that the GPS was taking a shortcut. After about a half-hour of traveling through winding streets, the GPS directed us up a hill and the pothole studded paved road gave way to dirt road. As we wended our way uphill, we witnessed a dog threesome—two mating, one watching—in the middle of the road. The sight of the unruly dogs was enough to initiate an abrupt change of course, as we were like pre-modern seafarers turning back from uncharted territory marked by the mapmaker's convention "here be dragons."[20] The guide directed me to stop beside a pedestrian who was walking downhill. In Spanish, he asked him about where the road led and if it was reliable. The fellow answered affirmatively, pointing toward the way we had been going up the hill. However, the guide seemed resolute at this point, and said he did not like the way this route was turning out, and we headed back by the route

we had come. Every kilometer or so, the guide indicated for me to pull over and he would ask directions from someone waiting for a bus, walking, or even jogging. As I understood it, with each stop for directions the guide was not only trying to verify the directions he had been given earlier, though I think that was an issue, he also was updating directions in a point-by-point way as we proceeded. It was both a way to check that we were still en-route and to "refresh" the directions from a new point along the way. Meanwhile, the GPS kept "insisting" that we revert to our previous, seemingly hopeless, route even after we joined the main highway. The guide shut off the GPS, and we made it to our destination without further mishap, though much later than we had initially planned.

It was clear in this case that the guide's trust in the machine was far from absolute, as he ended up completely disregarding the GPS and using other resources available in the environment, none of which was fully trusted either. The many permanent and impermanent features of the scene outside the vehicle, which were nowhere to be seen on the GPS screen, were overwhelmingly evident during the journey. These gratuitous details—gratuitous for the GPS instructions, but not for the driver and navigator—included pedestrians, unleashed dogs, potholes, and other hazardous features of the local road. The layout of streets in the hills made for confusing reading of the GPS, as it was difficult to see at a glance which of the network of roads was *the route*, even though the route to follow was clearly indicated by the magenta line on the GPS screen. Such streets were unlike a main highway, which is wider than the incoming streets, has clearly marked lanes and road edges, and is outfitted with multiple signed exits. The roads and traffic also were less "disciplined," as they included an indiscriminate mix of humans, animals, streets, intersections, and types of machines (cars, large trucks, motorbikes, bicycles). Such an environment, though far less congruent with the GPS's "world" than a modern cityscape and highway infrastructure (patches of which can be found in San Juan and Costa Rica, but not where we were at the time), also provided a resource—a legible backup system. Potholes and unruly dogs alerted us that we were off the beaten track, and the guide used the low-tech system of asking for local directions to repair the confusion and anomalous route sketched out for us by the GPS.

Discussion: Navigation as an Intertextual Achievement

The concept of tacit knowledge is often treated as a matter of *personal*, often nonverbal, knowledge (Polanyi 1958). The commonly used example of riding a bicycle—an embodied competence that is much easier to master than it is to articulate—suggests that tacit knowledge is embedded in the person, as a holistic assemblage of perceptual, motor, and cognitive skills that operates beneath language and is acquired through personal contact and example. As Collins (2010) emphasizes, tacit knowledge is not limited to personal somatic skill, since the cultivation of such skill arises from and is afforded by membership in the social groups (such as scientific disciplines) that sustain the relevant practices and establish the standards through which such skill is enacted and evaluated. Whether construed as personal or social, or both, tacit knowledge tends to be elucidated through contrasts to formal knowledge that takes the form either, or both, of written instructions for humans or as

programmed instructions for automatons. Accordingly, tacit knowledge extends beyond the limits of formal instructions and automated actions. However, when we examine examples such as those elicited through our exercises, not only do we discover how tacit knowledge is featured differently in navigational work, in relation to the specific formats of instruction used, we also have the opportunity to investigate just how we contend with the contingencies that arise on particular occasions. Although personal skills, habits, and abilities to improvise certainly are important, when we performed variants of the exercise, much of what guided us with, without, or in spite of the instructions we had at hand, and/or on screen, was embedded in the environment through which we navigated. Our examples included such social resources as the flow of pedestrians and directions from passers-by. However, they also included legible aspects of the built environment.

In our example of the Euclidean navigator, networks of material infrastructure (roads and fences), semiotic notifications (road signs), legal frameworks (one-way streets), and so on, block or prohibit any effort to get from A to B through the shortest possible route. As we have seen, however, these same barriers also provide resources for navigation. Navigation—with or without the latest digital tools—calls into play an intertwining of infrastructures (material pathways and barriers, systems of road signs, rules of the road), to bring them into alignment through an infrastructural mashup of paper maps, occasion maps, GPS, and so on, to practically accomplish a journey from A to B. By *infrastructural mashup*, we mean the ability of combine several different sources of information into a coherent context and source of guidance for any next action. A GPS combines information about these different infrastructures (material, road signs, legal speed limits, and so forth) into a unified interface that gives ongoing directions, but such directions become intelligible (or not) in relation to the multiplicity of other instructional resources at hand and in the local environment.

In a precursor to what later became known as infrastructure studies, Bruno Latour describes how legibility is on *both sides* of the gap between a map and the landscape:

> When we use a map, we rarely compare what is written on the map with the landscape—to be capable of such a feat you would need to be yourselves a well-trained topographer, that is to be *closer* to the profession of geographer. No, we most often *compare* the readings of the map with the road *signs* written in the *same* language. The outside world is fit for an application of the map only when all its relevant features have themselves been written and marked by beacons, landmarks, boards, arrows, street names and so on. The easiest proof of this is to navigate with a very good map along an unmarked coast, or in a country where all the road boards have been torn off (as happened to the Russians invading Czechoslovakia in 1968). (Latour 1987, 254, emphasis original)[21]

In this sense, a map does not simply represent what is "out there" in the environment. Both the built environment and the map deploy a coordinated array of signs and markings. Navigation is thus an intertextual achievement. A GPS device enhances legibility, not only by including names and directional arrows that correspond to those printed on road signs, but also by making gratuitous details and forbidden pathways disappear. Here, the GPS device is a Latourian (1992) mundane technology in the way it obviates and supplements signs, rules, and injunctions with an algorithm. It does not replace such infrastructure, but is instead

parasitic on it. Unlike infrastructures such as sewer systems, which are hidden beneath the surface of the urban landscape, and accessible only to specialists (or in the case of the Paris sewers, tourists), much of the infrastructure that affords street and sidewalk navigation is on the surface and out in the open. However, the GPS also systematically hides features in its doubled vision of that infrastructure. Blocked and forbidden paths simply do not exist in its display of possibilities, although as we learned when walking with a GPS along familiar pathways, like other digital rights management tools, the GPS also eliminates other paths and infrastructures that are available to "fair use" (Gillespie 2009).

Conclusion

So, what difference does this particular digital technology make for the familiar tasks of wayfinding? As we have discussed, using a GPS not only alters the gap between instructions and instructed actions in specific ways, but also alters the relationship users have with the environment through which they are navigating. A GPS device, in this context, draws together a distinctive set of relationships among constituents of the infrastructure for travel (roads, pathways, signs, and so on). Functionally, a GPS device used for navigating between A and B reconstructs the landscape to be traversed in specific algorithmic ways. It is not that other routes are inconceivable, it is rather that when the user chooses to take another route, the GPS prescribes a route for *that* journey, and it can do so for others ad infinitum. This mundane mode of prescription brings together pathways affording travel into an account of a singular, if ever-changing, route to be traversed during the journey. Considered in this way, a GPS is a distinctive kind of scalar device (Ribes 2014) whose legibility also requires a reading of the environment "out there," and both the device and the environment deploy established infrastructures composed of signs, signals, roads, walkways, and so forth. Occasions, such as those described above, when there is a mismatch between these two systems of legibility provide opportunities both to reflect upon the distinctive properties of the GPS *and* upon the legibility of the infrastructures in which its use is embedded. The GPS does not by itself close the gap between map and journey—indeed, as we have seen, it opens up as well as closes; it reproduces and reduces the legibility that is already present in the built environment.

Instances of getting lost instructed us that the infrastructural mashup is not a seamless web—there are many "infrastructural seams" (Vertesi 2014) to stumble over, and sometimes to exploit, in order to form local pathways and linkages in the course of a journey. And, now that it is far from novel, the GPS itself is a resource at the back end of a multiplicity of location services such as Uber, Foursquare, and so on. These services are parasitic on the GPS, just as it is itself parasitic on older forms of road maps, occasion maps, and verbal directions. GPS also is parasitic on orbiting satellites and cell phone towers that it taps into, even though they were not purpose-built for it.

While the word "parasite" has negative connotations (tapeworms and leeches, etc.), it also has broader theoretical relevance to constructive systems and relationships (Serres 1982; Brown 2013). Our reference to "parasitic infrastructures" thus means a borrowing of existing infrastructures for uses that differ from their dedicated purposes. Accordingly, we are treating infrastructures as manifestations of human ingenuity for instructed action in a built environment. Parasitic

infrastructures are pervasive in this sense. In line with Winthereik and colleagues' conception of "third wave infrastructure studies" (this volume), which focus on "experimental" borrowings from existing infrastructures to exploit their unanticipated uses, we suspect that many other information infrastructures are parasitic in the way they create infrastructural mashups, which need to be continuously recombined and worked upon in the course of achieving their dedicated purpose. To pursue this and other suggestions we have made in this chapter, we encourage our readers to use this chapter as a field guide for further exploration.

Acknowledgments

The authors are grateful to Yanni Loukissas, Shreeharsh Kelkar, and two anonymous reviewers for their helpful comments on earlier drafts of this paper.

Notes

1. The course (Science & Technology Studies 6251, Visualization and Discourse in Science) was taught by Michael Lynch at Cornell University in spring 2014. Ranjit Singh, Jessica Price, and Christopher Hesselbein were enrolled in the course. The professor and students performed the exercises in preparation for and in some instances as part of each weekly seminar.
2. Other assigned exercises involved performing classic experiments from published descriptions, following recipes for preparing a dish or making beer, tying knots described in diagrams (such as a Windsor knot for formal men's attire), and many others.
3. Interpretations of Ludwig Wittgenstein's (1953) treatment of actions in accord with rules provided a philosophical starting point for these investigations.
4. Further readings also were recommended and were used in both the design and interpretation of the exercise and the experiences associated with it: Psathas (1979, 1986), Psathas and Kozloff (1976), Wallace (2004), Garfinkel (2002, 197–218), Hutchins (1993), and Liberman (2013). Many other sources were brought into play during our discussions and are cited in this chapter.
5. Such a journey from A to B appears at first glance to highlight the elements of the "unit act" formulated by Talcott Parsons (1937, 43–48) as a sociological parallel to the Newtonian conception of motion. The essential elements of the unit act include an *actor*; a clear-cut *end*; a choice of *means* to efficiently realize that end; and culturally prescribed *normative considerations*, which encourage or deter the choice of one or another possible means to that end.
6. See Ziewitz's (2017) account of the troubles occasioned by walking in a way guided by a simple algorithm.
7. Such barriers and prohibitions are by no means limited to modern cityscapes. One of the examples Bourdieu (1977, 37–38) uses of *habitus* is a worn pathway through a village that generations of villagers have used and beaten into the landscape with their feet. When following a footpath, one frequently finds normatively sanctioned and unsanctioned (or specifically prohibited) pathways. Even with footpaths through natural parkland, there are signs stating the imperative to keep to the path, and at strategic points there are fences, barriers, and warning signs (complete with threats of arrest), which are contravened by improvised paths that cross the barriers into the forbidden zones. In a town or city, a material infrastructure of paved roads, curbs and other barriers, road signs, pedestrian directions, kiosks with city and campus maps, and so on leads the way with an integrated set of possible pathways. The conditions of possibility for the journey depend on the ways in which instructions for getting from A to B are framed, and as discussed later they are also limited and afforded by an infrastructure of constructed pathways.
8. Garfinkel (1967) famously devised exercises to deliberately *induce* trouble by disrupting familiar interactional routines. The troubles solicited through the exercises discussed in this chapter use a less disruptive strategy (and one more compatible with IRB requirements) that Brown and Laurier (2012) effectively use in their study of "normal natural troubles" arising through GPS navigation.

9. Our treatment of older navigational aids, as well as contemporary gadgets and apps, as "technologies" reminds us of a remark by a student of Janet Vertesi's who was new to science and technology studies: "I never thought of the bicycle or the car as technology" (Janet Vertesi, personal communication).
10. Not too long ago, when customers of the American Automobile Association (AAA) sought advice on planning a journey, an employee would use a marking pen (often with a bright color such as magenta) to trace a route on a road map. Nowadays, online direction maps retain that convention by marking a route with a similar magenta (or other brightly colored) line.
11. This term is a transformation of Bruno Latour's (1990) notion of "immutable mobile"—a map (or other rendering)—that is inscribed in a fixed medium and can be transported and reproduced without (at least in principle) changing its features. In contrast, a map at a kiosk that includes a singular reference point to "here" cannot be moved from its place without requiring erasure or revision of the deictic expression "here."
12. Kevin Lynch (1960) includes numerous examples of such maps in his classic treatment of the city. The London Underground map discussed by Vertesi (2008) is an interesting hybrid of an occasion map and a road (or in this case rail line) map. The Underground map is like a road map in its layout of a complete array of possible routes, independent of any particular journey, but like an occasion map it displays underground lines in a stylized, non-topographical way.
13. We use the term "Turing machine" here in the contemporary popularized sense of a "universal" machine that can be configured (programmed) to perform a broad range of tasks once associated with specialized human jobs and technologies: calculators, typewriters, word processors, and so on.
14. McCormick (2013), in a discussion of "mobility and the city" with smartphones in different international contexts, observes, "What is baffling, often times across class divides, are the ways in which our actual physical location becomes rendered on digital interpretations of space: on a colored screen, with a pulsing blue dot representing ourselves. This logic, portrayed through the cartography of services such as Google Maps, can be incomprehensible to someone who lacks the necessary literacy to read, interact, and decipher maps. This can then recast the physical-spatial representations we all have in our minds with the visual and experiential images we come to interact with in the city." He goes on to observe that the difficulty some friends of his in Cairo had in following directions he gave them in terms of such features on the screen "foretells an altered way of learning, being, and moving in the city. These virtual representations of our physical environments are like an electronic guide, to be followed on our screens, as we step over curbs, through traffic, and around corners, all the while connected and existing in space in a different way." We are grateful to Shreeharsh Kelkar for alerting us to this article.
15. This is akin to the gap Vertesi (2008) identifies between the London Underground map and the above-ground experience of surface travel in that city (itself often guided by maps such as the London A-Z).
16. From a phenomenological point of view, the GPS screen presents the user with a "small" world embedded in a more comprehensive lifeworld. But from an engineering point of view, the system in which that screen is embedded is "global" in scope and the user's situation is but a "micro" node in the information network. In the case of GPS devices, the visible interface on the small screen is a product of an invisible infrastructure of cell phone towers and satellites, together with the labor force that constructs and maintains it.
17. Repair in conversation was first discussed by Sacks et al. (1974, 723) and subsequently developed in conversation analysis. For development of the theme in the context of STS, see Sims and Henke (2012).
18. This turn in the exercise was analogous to some of Garfinkel's (1967) "experiments" that involved violations of normal routines (such as bargaining for prices of goods purchased in a supermarket) that revealed that seemingly inflexible rules were more open to negotiation than had previously been imagined.
19. See Liberman (2013, 62) on the confident beginnings of trips guided by occasion maps. In such cases, the journey starts from a known place and proceeds to an unknown destination, and the confidence tends to wane as the terrain becomes unfamiliar and the map directions become more difficult to correlate with features of the terrain.
20. See Vertesi (2008, 18) on variations of this convention in hand-drawn maps of London.
21. Brown and Laurier (2005, 18) recite another story (from Holub 1977) that can be positioned as a counterpoint to what Latour mentions about Russians invading Czechoslovakia. In this story, a

detachment of Hungarian soldiers sent into the Alps encountered a snowstorm, but the soldiers managed to find their way back from the wasteland. When asked how they achieved this navigational feat, they pointed to a map one of the soldiers had in his pocket. Upon closer inspection, however, it turned out to be a map of the Pyrenees. Accordingly, the map projected its legibility onto the blank canvas of the Alpine wasteland, inspiring and enabling the troupe to go on with its journey.

Works Cited

Agre, Philip, and David Chapman. 1990. "What Are Plans For?" *Robotics and Autonomous Systems* 6:17–34.

Bourdieu, Pierre. 1977. *Outline of a Theory of Practice*. Cambridge: Cambridge University Press.

Brown, Barry, and Eric Laurier. 2005. "Maps and Journeys: An Ethno-methodological Investigation." *Cartographica* 4 (3): 17–33.

———. 2012. "The Normal-Natural Troubles of Driving with GPS." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1621–30. New York: ACM.

Brown, Steven D. 2013. "In Praise of the Parasite: The Dark Organizational Theory of Michel Serres." *Porto Allegre* 18 (1): 83–100.

Collins, H. M. 1974. "The TEA Set: Tacit Knowledge and Scientific Networks." *Science Studies* 4:165–86.

———. 1975. "The Seven Sexes: A Study in the Sociology of a Phenomenon, or the Replication of Experiments in Physics." *Sociology* 9:205–24.

———. 2010. *Tacit and Explicit Knowledge*. Chicago: University of Chicago Press.

Dreyfus, Hubert. 1979. *What Computers Can't Do*. New York: Harper & Row.

———. 1992. *What Computers Still Can't Do: A Critique of Artificial Reason*. Cambridge, MA: MIT Press.

Garfinkel, Harold. 1967. *Studies in Ethnomethodology*. Englewood Cliffs, NJ: Prentice Hall.

———. 2002. *Ethnomethodology's Program: Working Out Durkheim's Aphorism*. Lanham, MD: Rowman & Littlefield.

———. 2008. *Toward a Sociological Theory of Information*. Boulder, CO: Paradigm.

Garfinkel, Harold, and Eric Livingston. 2010. "Phenomenal Field Properties of Order in Formatted Queues and Their Neglected Standing in the Current Situation of Inquiry." *Visual Studies* 18 (1): 21–28.

Gillespie, Tarleton. 2009. *Wired Shut: Copyright and the Shape of Digital Culture*. Cambridge, MA: MIT Press.

Goffman, Erving. 1972. *Relations in Public*. New York: Harper & Row.

Holub, M. 1977. "Brief Thoughts on Maps." *Times Literary Supplement*, February 4, 118.

Hutchins, Edwin. 1993. "Learning to Navigate." In *Understanding Practice: Perspectives on Activity in Context*, edited by Seth Chaiklin and Jean Lave, 35–63. Cambridge: Cambridge University Press.

Ingold, Tim. 2000. *The Perception of the Environment: Essays on Livelihood, Dwelling, and Skill*. New York: Routledge.

Jackson, Steven J. 2014. "Rethinking Repair." In *Media Technologies: Essays on Communication, Materiality and Society*, edited by Tarleton Gillespie, Pablo J. Boczkowski, and Kirsten A. Foot, 221–39. Cambridge, MA: MIT Press.

Latour, Bruno. 1987. *Science in Action*. Cambridge, MA: Harvard University Press.

———. 1990. "Drawing Things Together." In *Representation in Scientific Practice*, edited by M. Lynch and S. Woolgar, 19–68. Cambridge, MA: MIT Press.

———. 1992. "Where Are the Missing Masses? The Sociology of a Few Mundane Artefacts." In *Shaping Technology/Building Society: Studies in Sociotechnical Change*, edited by W. E. Bijker and J. Law, 225–58. Cambridge, MA: MIT Press.

Laurier, Eric, Barry Brown, and Moira McGregor. 2016. "Mediated Pedestrian Mobility: Walking the Map App." *Mobilities* 11:117–34.

Leshed, Gilly, Theresa Velden, Oya Rieger, Blazej Kot, and Phoebe Sengers. 2008. "In-Car GPS Navigation: Engagement with and Disengagement from the Environment." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1675–84. New York: ACM.

Liberman, Kenneth. 2013. "Following Sketch Maps." In *More Studies in Ethnomethodology*, 45–82. Albany: State University of New York Press.

Lipartito, Kenneth. 2003. "Picturephone and the Information Age: The Social Meaning of Failure." *Technology and Culture* 44 (1): 50–81.

Lynch, Kevin. 1960. *The Image of the City*. Cambridge, MA: MIT Press.
Lynch, Michael. 2013. "At the Margins of Tacit Knowledge." *Philosophia Scientiæ* 17 (3): 55–73.
McCormick, Jared. 2013. "The Whispers of WhatsApp: Beyond Facebook and Twitter in the Middle East." *Jadaliyya*, December 9. Available at: www.jadaliyya.com/pages/index/15495/the-whispers-of-whatsapp_beyond-facebook-and-twitt.
Medawar, Peter. 1964. "Is the Scientific Paper Fraudulent? Yes; It Misrepresents Scientific Thought." *Saturday Review*, August 1, 42–44.
Merleau-Ponty, Maurice. 1962. *Phenomenology of Perception*. London: Routledge & Kegan Paul.
Merton, Robert K. 1938. "Social Structure and Anomie." *American Sociological Review* 3 (5): 672–82.
November, Valérie, Eduardo Camago-Hübner, and Bruno Latour. 2010. "Entering a Risky Territory: Space in the Age of Digital Navigation." *Environment and Planning D: Society and Space* 28:581–99.
Parsons, Talcott. 1937. *The Structure of Social Action*. Vol. 1. New York: Free Press.
Polanyi, Michael. 1958. *Personal Knowledge*. Chicago: University of Chicago Press.
———. 1962. "Tacit Knowing: Its Bearing on Some Problems of Philosophy." *Review of Modern Physics* 34 (4): 601–16.
Psathas, George. 1979. "Organizational Features of Direction Maps." In *Everyday Language: Studies in Ethnomethodology*, edited by George Psathas, 203–26. New York: Irvington.
———. 1986. "Some Sequential Structures in Direction-Giving." *Human Studies* 9 (2/3): 231–46.
———. 1990. "Direction-Giving in Interaction." *Réseaux* 8:183–98.
Psathas, George, and Martin Kozloff. 1976. "The Structure of Directions." *Semiotica* 17:111–30.
Ribes, David. 2014. "Ethnography of Scaling: Or, How to Fit a National Research Infrastructure in the Room." *CSCW*, February 15–19.
Sacks, Harvey, Emanuel Schegloff, and Gail Jefferson. 1974. "A Simplest Systematics for the Organization of Turn-Taking in Conversation." *Language* 50 (4): 696–735.
Serres, Michel. 1982. *The Parasite*. Baltimore: Johns Hopkins University Press.
Sims, Benjamin, and Christopher R. Henke. 2012. "Repairing Credibility: Repositioning Nuclear Weapons Knowledge after the Cold War." *Social Studies of Science* 42 (3): 324–47.
Suchman, Lucy. [1987] 2007. *Human Machine Reconfigurations: Plans and Situated Actions*. 2nd ed. New York: Cambridge University Press.
Vertesi, Janet. 2008. "Mind the Gap: The London Underground Map and Users' Representations of Urban Space." *Social Studies of Science* 38 (1): 7–33.
———. 2014. "Seamful Spaces: Heterogeneous Infrastructures in Interaction." *Science, Technology, & Human Values* 39 (2): 264–84.
Wallace, Anthony F. C. 2004. "Driving to Work." In *Modernity and Mind: Essays on Cultural Change*, Vol. 2, edited by A.F.C. Wallace, 17–33. Lincoln: University of Nebraska Press.
Wittgenstein, Ludwig. 1953. *Philosophical Investigations*. Oxford: Blackwell.
Ziewitz, Malte. 2017. "A Not Quite Random Walk: Experimenting with the Ethnomethods of the Algorithm." *Big Data & Society* 4 (2): 1–13. https://doi.org/10.1177/2053951717738105.