Digital Technologies In Orientation And Mobility Instruction For People Who Are Blind Or Have Low Vision

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This paper investigates the tools and practices used by Orientation and Mobility (O&M) specialists in instructing people who are blind or have low vision in concepts, skills, and techniques for safe and independent travel. Based on interviews with experienced instructors who practice in different O&M settings we find that a shortage of qualified specialists and restrictions on in-person activities during COVID-19 has accelerated interest in remote instruction and assessment, while widespread adoption of smartphones with accessibility support has driven interest in assistive apps. This presents both opportunities and challenges for a practice that is traditionally conducted in-person and assessed through qualitative observations. In response we identify multiple opportunities for HCI research in service of O&M, including: supporting a 'physician's assistant' model of remote O&M instruction and assessment, matching O&M instructors' clients with guide dogs, highlighting clients' progress towards O&M goals, and collaboratively planning routes and monitoring clients' independent travel progress.

CCS Concepts: • **Human-centered computing → Empirical studies in HCI**; **Empirical studies in interaction design**.

Additional Key Words and Phrases: Orientation and Mobility

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1 INTRODUCTION

Orientation and Mobility (O&M) is the specialist practice of instructing people who are blind or have low vision in concepts, skills, and techniques, associated with safe and independent travel in familiar and unfamiliar locations [21, 38, 122]. This paper presents our inquiry into how O&M specialists use digital technologies within their work practice. To explore this topic, we report on

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our findings from semi-structured interviews with eleven experienced Certified Orientation and Mobility Specialists (COMS) who come from different locations across the US, and work in a range of contexts with differing population groups. In these interviews we investigated how digital tools are currently used in O&M practice, and also probed on opportunities for their possible future use by O&M specialists, introducing low-fidelity design prompts as conversation starters. While there is a rich history of HCI research that directly addresses the needs, desires, and concerns of people with differing degrees of visual impairment, to our knowledge HCI inquiry probing the work of O&M specialists who serve this population has to date been much more limited. We respond to this gap by paying particular attention to better understanding the variety of experiences of O&M specialist practitioners, and as a result we do not report on the experiences of their clients in this paper.

1.1 Background to the Practice of Orientation and Mobility Instruction

O&M instruction is typically done one-to-one in-person and can take place at a variety of locations dictated by the needs of the person receiving instruction. This makes it both time-consuming and labor-intensive, and limits the amount of support that is typically available to individuals. Instruction involves cognitive, behavioral, social, and problem-based learning [32], and may be habilitative in the case of congenital visual impairment or rehabilitative where visual impairment is adventitious. The key skills for O&M learning come under six broad categories [42, 103]: (1) *Self-Protective* Orienting to the home environment and neighborhood, and avoiding being hurt when moving around without any mobility device; (2) *Human Guide:* Using verbal and non-verbal techniques for walking safely with another person; (3) *Cane Skills:* Using a long white cane to detect information about the environment necessary for safe and independent travel; (4) *Non-Visual Skills:* Focusing on information such as sound, textures, timing, orientation and mental maps to safely and independently walk on sidewalks, cross streets, and travel by bus and subway; (5) *Route Planning:* Getting information about a destination and how to reach it, using prior knowledge and adding different resources before and during travel; and increasingly (6) *Accessible GPS Technology:* using accessible travel and navigational applications.

In the US, where this research is focused, O&M specialists become certified practitioners through either the National Federation of the Blind (NFB) or the Academy for Certification of Vision Rehabilitation and Education Professionals (ACVREP). This is typically achieved through a university graduate program in Orientation and Mobility. Certified O&M instructors (COMS) can work with people of all ages from pre-school through to older adults, or specialize in particular populations. They may be based in a single institution or work itinerantly, and are a diverse population seeking to support the learning needs of another highly diverse population. The prevalence of visual impairment in those over 40 years of age in the US was estimated at 2.94% in 2010, varying from 0.31% for those aged 40-49 to 25.66% for those over 80 [52]. Although not all of these people will seek the help of O&M specialists, their visual impairments are likely to lead to reduced mobility and social participation, which can result in reduced independence and diminished quality of life [90]. For people who are blind or with low vision, O&M specialists are a key resource in helping increase independence and enhance employment likelihood [12].

While O&M specialists may refer to the person receiving instruction as their client or their student, or occasionally their patient, for consistency we use the term clients throughout this paper. The exception being where participant quotes are used to illustrate our findings and that participant has chosen to use an alternative term.

1.2 Contributions

Based on our qualitative analysis of semi-structured interviews with experienced O&M specialists, we characterize opportunities and challenges that result from a) an accelerated interest in remote O&M instruction and assessment, and b) widespread adoption of smartphones with accessibility support; and offer two main contributions:

(1) *An investigation into the tools and practices used by O&M specialists.* This is an important domain that is facing increasing demand from an aging population and has to our knowledge been the subject of limited prior HCI research. As a result, the HCI and CSCW community knows little about the challenges O&M instructors face, their current workaround solutions, or the potential for HCI to make a positive impact in this area.
(2) *Four opportunities for HCI research in service of O&M practice.* (1) Supporting a 'physician's assistant' model of remote O&M instruction and assessment; (2) matching O&M instructors' clients with guide dogs; (3) highlighting clients' progress towards O&M goals; and (4) collaboratively planning routes and monitoring clients' independent travel progress.

2 RELATED WORK

While HCI has a longstanding and well recognized relationship with people who are blind or with low vision, this research has focused on tools to directly support end-users in everyday activities. Interest in the work of professional O&M instructors has been more limited. Because of this we provide an overview of related work in two distinct areas. First we discuss the limited amount of HCI research that has engaged directly with the professional practice of O&M instructors, which focuses mainly on efforts to improve access to and interaction with tactile maps. Following this we discuss HCI efforts to provide tools that aim at augmenting or even replacing the skills traditionally taught by O&M instructors. Here we look at research into navigation and wayfinding, and then remote assistance and obstacle avoidance. This is not meant as a comprehensive review of the extensive body of HCI research that addresses accessibility and mobility issues for the blind and low vision communities, but rather to provide an overview to topics considered interesting to the HCI community as they intersect with the practice of O&M instruction.

2.1 HCI Research into Orientation & Mobility Instructors' Practice

While HCI research directly focused on support for O&M instructors and their practice has to date been limited, one area of focus has been improving on tactile maps. Tactile maps are a familiar O&M tool that are used to help people with impaired vision develop mental models of unfamiliar locations [109]. Comparisons show that 3D printed maps may offer benefits over traditional tactile maps [49, 50], and that a combination of verbal explanations and 3D printed tactile maps can have benefits over verbal explanations alone [84, 116]. Research has also led to the development of accessible tools to support easier and more flexible creation of low-cost 3D tactile maps, e.g. [104, 112], while augmented reality may offer a flexible alternative to 3D printed and other tactile maps [4].

Moving beyond tactile maps, Regal et al. [89] present a mobile location-based game to support advanced O&M training, where students are already familiar with a building layout. Façanha et al. [31] review literature on O&M indoor virtual environments, finding that few studies evaluate cognitive impact. Papadopoulos et al. [83] investigate user requirements for students who use O&M aids to navigate campus, finding that safety and locating services were above wayfinding and orientation in order of importance. Thevin, Briant and Brock [113] investigate VR as a tool to support O&M training, suggesting areas in which it can be effective and offering design recommendations for inclusive VR systems. Holmes and Prentice [51] investigate remote O&M support for an

experienced independent low-vision traveller using FaceTime, finding it offered opportunities to increase independence. Baker, Milne and Ladner [8] investigate the impact that specialist teachers have on assistive technology selections made by students with low vision, identifying research areas for assistive technology design. However, these examples have tended to be somewhat adjacent to O&M instructors primary activities, and focused on younger school-aged or student clients.

2.2 HCI Research into O&M Tools for People With Impaired Vision

2.2.1 Navigation and Wayfinding Tools for People With Impaired Vision. Most HCI research of tools to support wayfinding and navigation for people with impaired vision has focused on end users who are already experienced independent travellers. For example, Kameswaran et al. [56] investigate commonly available technologies, offering design recommendations to enhance complementarity, and Gupta et al. [43] suggest design guidelines to support universally accessible wayfinding. Indoor wayfinding systems based on mobile applications and Bluetooth beacons e.g. [37, 40, 98, 99] offer enhanced independence to confident experienced travellers in complex contexts such as airports. Audible Bluetooth beacons are also proposed as a way to support increased independence and inclusion for school children with low vision [34]. Alternative approaches to indoor wayfinding have been based on a crumb trail metaphor that includes recording and backtracking elements, e.g. [33, 91, 126], or use stationary robots, e.g [111]. For outdoor navigation, GPS systems are also effective for experienced travellers [54, 55, 96], although GPS inaccuracies lead to challenges such as the last-few-meters problem [94]. Intersections and road crossings provide another challenge for outdoor wayfinding. Guy and Truong [44] describe a system for providing intersection geometry and a protocol for crowdsourcing description data; suggesting this could benefit confident independent travellers in unfamiliar locations. Abdolrahmani et al. [1] suggest that users have a high degree of tolerance for system navigation errors, where they are not likely to have negative social consequences. However, rotation errors in turn-by-turn navigation guidance can be accentuated for slight turns and then amplified by forward movement [2]. Guerreiro et al. [39] compare turn-by-turn and point-of-interest navigation guides, finding that each approach is effective but that context and goal are important in assessments of value.

More broadly, Banovic et al. [10] investigate practices people with impaired vision use in learning about and navigating environments, finding that informational needs are not met by existing assistive technology. Similar findings result from studies by Engel et al. [29] who survey about preparation strategies for journeys to unfamiliar buildings, and Zhao et al. [129] who investigate navigation in environments with surface level changes, such as stairs. Williams, Hurst and Kane [123] suggest design recommendations that reflect the changing needs people with impaired vision have with regards to navigation support technology; while Cuturi et al. [26] suggest assistive technologies for supporting blind and low vision users' mobility typically pay too little regard to brain mechanisms and aim at substituting vision without offering rehabilitation training. Hersh [47] offers guidance for how an understanding of the way people with impaired vision use mental maps might inform the design of travel aids. Other approaches, such as May et al. [73] investigate mixed reality environments as an alternative way of forming mental maps, highlighting the need to include future users in design. Computer based video games [74] and audio based virtual environments [23] have also been shown to be effective in helping people with severe vision loss to learn the layout of unfamiliar buildings and acquire skills for understanding spatial layout.

2.2.2 Remote Assistance and Obstacle Avoidance. In recent years, remote assistance from sighted people or via computer vision and AI algorithms has begun to offer people with impaired vision a new form of digitally-mediated support for wayfinding and object identification. These practices are found to be made up of highly context dependent interactions [64], with support from trained

and untrained guides not being equivalent [57]. Requesting this type of remote guidance via social networks may not be considered appropriate by potential users due to perceived social cost [15]. Privacy is another key concern for systems that are typically based on a feed from the user's cell phone camera, which may limit their social acceptability [3] or require strict protocols around handing sensitive data [108]. Recent years have also seen the development of systems for obstacle avoidance [5], including avoiding other people in crowded environments, e.g. [41, 58, 88]. Feedback to the user is an essential aspect of obstacle avoidance, and here HCI research has focused on the comparison of different feedback modalities. Typically this has fallen into a choice between providing feedback in the form of audio, e.g. [110], and audio-visual, e.g. [128], cues and haptic or tactile feedback, e.g. [6, 77, 125, 127]. However, tactile working memory has been found to be reduced when walking and in the presence of distracting sounds [30]. Another area of recent interest, which may support greater mobility for people with impaired vision is autonomous vehicles. Brinkley et al. [19] find both optimism and concern about their capacity to deliver on this promise; while Brewer and Kameswaran [18] offer design guidelines framed in terms of control and independence.

2.3 Summary and Opportunities

While an aging population is likely to lead to increased demand for O&M support, prior literature has tended to focus on the role of technology in directly supporting people with impaired vision, and paid little regard to the ways technology might augment or enhance the work of the O&M specialists who provide professional instruction. We begin to address this gap in prior research by undertaking a broad HCI inquiry into the current and possible future use of digital technologies by O&M specialists within their practice.

3 METHOD

In this section we describe our empirical method. First we describe how data were collected through interview and survey, and following this our qualitative analysis approach.

3.1 Recruitment and Data Collection

This research was conducted under the approval of our University's Institutional Review Board (IRB-FY2020-4182). Data were collected through online survey, video interview, and follow-up email discussions. Initially we recruited fourteen experienced O&M practitioners (9 female and 5 male) from across the US for our online survey. Recruitment was via messages posted on the Association for Education and Rehabilitation of the Blind and Visually Impaired (AER) Certified Orientation and Mobility Specialists website and Vision Rehab Forum, and through the extended network of authors five and six who each have many years close involvement with O&M research and practice. To probe more deeply, we then recruited eleven O&M practitioners (7 female and 4 male) for interview. Eight of these were participants from our survey, and a further three recruited through our network. For participant details see Table 1.

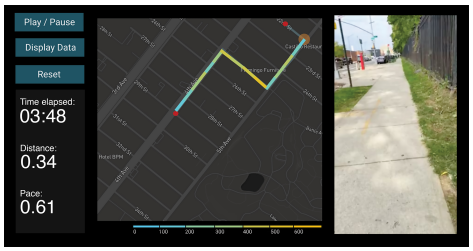
3.1.1 Survey. Our first round of data collection was an online survey. This survey was designed as a vehicle to screen and recruit participants for a more in-depth interview, and consisted of 12 mainly free text questions. These questions probed on topics including: (1) the participant's current role; (2) current challenges to O&M practice and possible solutions; (3) how clients' goals and other O&M outcomes are evaluated; and (4) how overall mobility is characterized and possible roles for quantitative metrics and digital technologies in O&M practice. See appendices for a full listing of questions. Participants were compensated $20 for completing the survey, and we used responses to help frame interview questions.

Table 1. Overview of participants. (* S = Survey, I = Interview)

ID	Participation*	Professional Role	Experience
P1	S & I	O and M instructor specializing in children and school-aged population	14+ years
P2	S & I	O and M specialist at State School for the Blind and Visually Impaired	20+ years
P3	S & I	O and M specialist at rehabilitation hospital	not stated
P4	S & I	O and M instructor at non-profit specialist with deafblind clients	10+ years
P5	S & I	O and M instructor, teacher and academic researcher	5+ years
P6	S & I	O and M instructor at non-profit	4+ years
P7	S & I	O and M instructor at non-profit	10+ years
P8	S & I	O and M instructor for State service program	20+ years
P9	I	O and M supervisor for national non-profit	20+ years
P10	I	O and M instructor at national non-profit	8+ years
P11	I	O and M instructor specializing in guide dog instruction	8+ years
P12	S	O and M instructor at non-profit	10+ years
P13	S	O and M instructor at non-profit	20+ years
P14	S	O and M instructor at non-profit	20+ years
P15	S	Itinerant O and M instructor	15+ years
P16	S	O and M teacher in schools	6+ years
P17	S	O and M instructor at non-profit	20+ years

3.1.2 Interviews. Semi-structured interviews were conducted with eleven O&M instructors (7 female and 4 male), whose level of professional experience ranged from a minimum four years to well over twenty years. Interviews took place over Zoom and were recorded. Interview duration was between 26 and 63 minutes (mean 47 minutes), and participants were compensated $35. In these interviews, we probed more deeply on (1) the participants' backgrounds and current roles; (2) on assessment methods and metrics; (3) on their experiences with remote O&M training or assessment, particularly in light of COVID-19 restrictions; and (4) on experiences using digital technologies in O&M. A full listing of questions is included in appendices. To initiate conversations about how digital tools might impact O&M practice in the near future we presented two different low-fidelity design prompts (discussed below). The design prompts were introduced towards the end of each interview after participants had given their initial responses to questions, including those concerned with digital technologies in O&M and remote O&M training and assessment. Following the Zoom interviews we continued to be in contact with participants to clarify points raised and ask follow-up questions. These follow-ups were conducted over email, and involved conversations with nine of the interview participants that ranged from short conversations of a couple of rounds of back and forth to more involved conversations that covered multiple topics over six or seven rounds of email. These longer email conversations were with participants P2, P4, and P9.

3.1.3 Low-fidelity design prompts. Towards the end of each interview, and after participants had shared their initial perspectives on the topics of concern, we introduced two low-fidelity design



(a) Low-fidelity prototype interface, used as a discussion prompt. The interface includes example representations of data that could be gathered using a smartphone.

(b) Chest-mounted smartphone and still frame from video recorded using this mount that provided a prompt during interviews.

Fig. 1. Two different low-fidelity prototypes were used to prompt conversation about how digital tools might be used in near-future O&M practice: a) a mock-up interface depicting data mapping; and b) video recorded from a chest-mounted smartphone.

probes to prompt conversation about how digital tools might impact the near-future work of O&M specialists. Figure 1 (a) shows a mock-up interface of a map that visualizes a route an O&M instructor's client might take as independent practice. We suggested to participants that one example of use could be to visualize ambulation data, such as pace and distance travelled, linked to GPS location. Figure 1 (b) shows a photograph of a chest-mounted smartphone and a screenshot from video recorded using the chest-mounted smartphone. Participants were shown video that had been recorded using the chest-mounted smartphone camera in both inside and outside settings. This was used as a prompt to spark discussions around asynchronous and synchronous remote O&M tuition and assessment. We selected these particular prompts because smart phones are seen as increasingly ubiquitous, including by people with impaired vision, and because these examples could address work currently undertaken during in-person tuition and assessment but in the context of remote interactions. This is a topic that was previously considered a challenge primarily relevant to providing O&M services to remote rural communities [11], but has seen increased attention following COVID-19 restrictions to in-person activities. In addition, it is also seen as one potential response to a current shortage of qualified O&M specialists, which is happening just as an aging population suggests demand for O&M instruction will increase [28, 79, 100]. We kept the prototypes intentionally low-fidelity in order to explore possibilities, negative as well as positive, and avoid in-depth evaluation of a particular idea. It is not our intention to suggest that these are the only examples of digital technologies that could have been presented to participants, or that these are the only uses of smartphones that will impact near-future O&M practice. Their role was to provide a starting point for conversation that could follow our participants' lead. However, we also acknowledge that the selection and use of design prompts necessarily primes participants towards directions of thought.

3.2 Analysis

Survey responses were exported and participants' answers to questions extracted. An individual spreadsheet was then created for each question, collating participants' responses. Interview recordings were transcribed. Analysis of these data was guided by two main sources, Seidman's guidelines for approaching interview data [102], and Braun and Clarke's approach to thematic analysis [16, 17, 69]. In each of these approaches, the key activity is drawing connections across sources through themes or threads, rather than attempting to articulate a unifying theory, which is

Table 2. Summary of findings

Theme	Brief Summary
4.1: Context of O&M Practice	We contextualize O&M practice and describe instructors' relationships with clients and their support networks, before outlining the range of clients' smartphone experience.
4.2: Using and Teaching GPS and Wayfinding Apps	We characterize participants' differing experiences in using and teaching assistive GPS apps with their clients.
4.3: Remote Instruction and Assessment	We characterize participants' experiences with and thoughts about remote O&M instruction, highlighting how this can be facilitated by a client's support network and discussing when it remains inappropriate.
4.4: Emerging Practices and Opportunities	We discuss some of the adhoc practices and workarounds that are emerging through participants' adoption of smartphones.

more typically the aim with grounded theory approaches. Analysis started with an initial familiarizing stage, in which the survey responses and transcripts were read, and interview recordings viewed and reviewed. Transcripts were then reorganized, based on the interview questions, to bring together different participants' responses. Key passages of interest were highlighted and initial codes applied, using an open coding scheme. Connections were then drawn between coded survey and interview data, to generate initial themes, which were further refined through an iterative process of interpretation and agreement reaching. Three researchers conducted this analysis, which was led by the first author. Our analysis was then presented back to all interview participants for member checking [25], and adjusted accordingly. Email responses to follow-up questions were collated and analyzed in a similar way to interview transcripts. Following this we presented a second round of findings back to participants for additional member checking and updating.

4 FINDINGS

In this section we present the results of our analysis, broken down into four main sections. First, we present an overview of the context in which O&M instruction takes place, as described through the perspectives of participants. We then present participants' experiences using and teaching GPS and wayfinding apps. Following this we present participants' perspectives and experiences with regards to remote instruction and assessment. Finally we identify emerging practices and new opportunities as they relate to the use of digital technologies in the work practices of O&M instructors. Within these four sections, our results are further organized by the themes that emerged from our analysis. See Table 2 for a summary overview of our findings.

4.1 Context of Orientation & Mobility Practice

O&M instruction has received limited previous attention from HCI research, and so before presenting our findings with regards to digital tools we briefly contextualize O&M practice from the perspectives of our participants. It was clear from our interviews that there are many routes into O&M, and while none can be considered typical it was common for participants to highlight a particular experience as introducing them to a career they would likely not have considered otherwise. There was also a wide variety in the clients that participants work with and settings for their instruction. The key objective for O&M instructors is to help reduce clients' dependency, and

increase their opportunities for independent or interdependent participation in everyday activities. However, relationships between an O&M instructor and their client require sensitivity. Participants described the way older clients come to terms with vision loss as like a process of grieving. For example, P2 told us that *"For the most part, people want to resume life as they knew it and generally become more willing, but there are those who hold out and live in uncomfortable ways while they go through the psychological acceptance process. Kind of like when a loved one dies; everyone experiences loss differently"*. At the other end of the age spectrum, P1 explained that coming to terms can also be difficult for clients who are school-age, *"A lot of my students, even my totally blind students, well into high school, are continuing to struggle with their own identity as a blind person. Some of my kids very early on, accept it and high five it. It's all good, they don't care. But some of my kids continue to be quite insecure about it"*. Because of this, and because instructors are often asking clients to push themselves into new challenges, O&M is a context in which trust is very important. Undertaking O&M is also likely a major change to a client's lifestyle that can have implications for other medical conditions, such as diabetes, and instructors must prepare themselves and their clients for the possible implications of this. These relationships extend beyond the client to their network of friends and family, as their capacity to offer support that encourages independence and provide opportunities for continued practice beyond instruction sessions is important to O&M success. First access to O&M training may come through school services or be sought later in life, while additional O&M help may be sought when a client takes a new job or moves to a new neighborhood, when they decide to seek a guide dog, or following a life changing event such as the loss of a supportive friend or family member. However as P5 explained, the capacity for core skills associated with O&M can vary in the sighted as well as in people with low vision, *"There are some people who don't know their left from their right, and there's other people who can tell you how many blocks they went down and if they went north, south, east, west. It's highly variable, it's not necessarily related to vision, but it makes a big impact on that person's ability to navigate independently"*. Just one of the O&M specialists we interviewed identified as having a vision impairment themselves.

4.1.1 Clients' Experience With Smartphone Assistive Technologies. One reason that digital tools are starting to become a part of O&M practice is the increasing ubiquity of smartphones, and nearly all participants commented that owning a smartphone has become commonplace among their clients. P2 explained how this was important in offering a respite from feeling different, *"Especially for our young people, who are going through that adolescent adjustment, they don't want to use anything that's different, that sets them apart. But a smartphone, oh my goodness, it's just the same thing everybody else wants"*. Clients new to O&M were also considered likely to be new to more advanced assistive features such as screen readers. Instead they might use a magnifier, increase text size or become more reliant on voice assistants. Older clients may also need to learn lower-tech devices such as a talking watch or glucose monitor first. Countering the view of smartphone ubiquity, P8 suggested *"With the population I'm with now, older blind, many of them can't even dial their telephones"*.

4.2 Using and Teaching GPS and Wayfinding Apps

As smartphone use increases amongst people with impaired vision it is becoming expected that O&M instructors be familiar with the GPS and wayfinding tools they offer. We found that all participants were at least familiar with the GPS tools in Apple and Google maps, that many are meeting clients who are keen to use them, most are introducing them into their practice with at least some of their clients, and that a few are regularly teaching clients how to use a variety of apps. When we probed participants on the impact of this on their O&M practice we found two broad groups. Those who are more experienced and are using and teaching GPS apps, and others

with less experience who do not currently teach GPS use in their O&M instruction. The first group were largely positive about the potential of GPS apps to add value, and suggested that digital technologies do not fundamentally change the relationship they have with clients, but can improve their clients' quality of life and may even become as integral to O&M as the white cane is now. For example, P10 told us, *"I think it makes it easier, because a lot of my students learn how to use Where am I? and Google maps if they ever get lost. I've had students, even students with cognitive delay, who know that if they get lost anywhere they can go to Where am I? and do a screenshot, because there will be a map of where they are. Then they can attach it to a text and send it to me"*. P7 specializes in teaching assistive GPS apps to clients and trains other O&M instructors to use and teach these tools. Placing clients in 3 broad categories, P7 discussed how an 'emerging tech learners' group of clients might use GPS to help confirm their current location, e.g. by asking Siri 'Where am I?'; while 'intermediate tech learners' might learn GPS for planning and completing routes, e.g. by saving markers. The third 'advanced tech users' group are more likely to be younger clients with congenital vision impairments, and P7 told us that *"They can do everything. They can type. They can deal with dynamic screen changes. They can get lost and get lost on their own. They don't need me to hold their hand all the way through it. So those are the folks that I'm going to probably teach them whatever APP they want to learn"*.

The views of the second group of participants ranged from those who are keen to learn and teach a new skill, through those who consider learning GPS to be a high-end skill that requires clients to first be able to travel proficiently and so is outside the typical scope of O&M instruction, on to those who were just not convinced that GPS apps offer value. For this final subgroup of participants, personal use of tools such as Google maps was described as being 'annoying' and 'confusing' because they are 'so repetitive'. These participants said that their focus would remain on training clients to travel safely using a cane. P9 suggested how clients can start learning and practicing GPS apps in 'passenger mode' saying, *"GPS is a great tool to use to understand your surroundings, to understand what streets you're passing, and whether you are on the right route. You can eventually start helping the person who's driving you with alternative routes. It's a great place to start because there's no pressure"*. However, it is also important to note that none of our participants suggested GPS apps would, could, or should replace the white cane as the primary tool for O&M. As P8 put it, *"I think fundamentally white cane training is is pretty much gold standard, and if you're proficient at that then you can step into those GPS apps"*; while P3 told us, *"I don't trade a white cane for an app"*.

4.3 Remote Instruction and Assessment

Recent experiences associated with restrictions on in-person activities due to COVID-19 have provided a new impetus to considerations of what remote instruction and assessment might be appropriate for O&M specialists and clients. Most common was using Zoom or FaceTime to teach clients O&M concepts such as cardinal directions and route planning, or to practice using assistive apps. Around half of participants discussed having direct experience of developing these type of activities, which they thought likely to continue to play a role in their instruction after restrictions have been eased. A key caveat to this was the importance of a client's support network. For example P2 told us, *"We still often require the assistance of someone on the other side, not for every student, some students I could, for instance, take my phone and put an APP up on the screen and we could learn the APP together. But for some students, they need someone to facilitate, or even just to hold a camera"*. One area of O&M practice that was already often remote is the initial assessment, which can take place over the phone. For example P6 told us, *"My first assessment with a client is usually over the phone. We have a list of questions that we go through. We ask them, how do you get along at home? how do you get along indoors? and unfamiliar areas? How do you get along outdoors? and also*

unfamiliar areas? Do you use public transportation? Can you plan a route? Basic questions like that". Participants discussed this as an obvious opportunity for future development when we showed them the video prompt. For example P9 said, *"To be able to view a home route, both indoors and outdoors, would be everything because of how much time we spend just trying to talk about where do you go? what do you do? who do you travel with?".*

O&M instructors' typically assess their clients' progress through direct observation often, although not always, during instruction. Four participants discussed attempts at replicating this kind of observation remotely, with mixed levels of success and enthusiasm. Once again we found that having the support of a friend or family member is crucial, as the O&M instructor needs that in-situ assistant to be both the camera person and the safety person. For example, P7 told us, *"It is better to coordinate with a family member to be the camera person, because then I have a bigger field of view. I can tell them exactly where to stand. I can ask them, 'hey did this thing just happen?', because if there's a delay and I'm missing something, they're sighted, so they might have other things that they can see that the student can't see".* However, safety always remains a primary concern and while teaching clients to safely cross streets is a key aspect of O&M instruction none of our participants considered it possible to do this remotely. P10 explained, *"Just by the nature of what we teach its potentially very dangerous. I can't tell somebody this is how you've got to cross the street, and not be there to see if they're doing it the way I tell them to"*; while P6 told us, *"You can't hear the traffic. You can talk about near parallel traffic, you can talk about the surge, you can talk about camber, you can talk about all of that, and alignment. But you have to get out in the street and do it".*

4.4 Emerging Practices and Opportunities

We also found that some participants are thinking about or experimenting with new uses for digital tools. The clearest emerging development we found is that around half of participants are considering how they might teach and use adaptive apps, such as Aira [1], a service that uses professional sighted agents to provide visual information for subscribers; BeMyEyes [2] a similar service but crowdsourced from volunteers; Seeing AI [3], a service built on machine vision; and GPS apps that are designed specifically for visually impaired users, such as BlindSquare [4]. P4 explained both the positive use cases and the limitations of theses apps when discussing Aira, *"I'll have them use it if they're in a store and they need to quickly locate something or even at an intersection to get an idea of what the intersection looks like real quick, but of course Aira can't tell you it's okay to cross the street".* Similarly, P5 explained why some service models might be more appropriate than others, and suggested that the value of crowd-sourced support is likely limited, *"BeMyEyes has a lot of issues from talking to people about it, because it's not a professional thing, it's just whoever, and I don't think that's necessarily great. If you want somebody to read what's on a piece of paper in front of you, okay, that's fine. But for navigation, it has more negative outcomes than positive outcomes, because people don't understand how to guide a blind person around if they're not used to it".* Other opportunities or emerging practices were discussed by just one or two participants, however they offer pointers to where near-future O&M practices may be heading. For example, even when clients are experienced independent travellers long distance journeys can be challenging, and P10 described using Apple's Find My service to remotely monitor how a client's travel progresses. Find My is a service first designed for locating lost Apple hardware, which was then adapted to locate selected contacts through the GPS coordinates associated with their iPhone. As with all the situations we discussed, safety is the paramount concern, and these examples rely on confidence

[1] https://aira.io/
[2] https://www.bemyeyes.com/
[3] https://www.microsoft.com/en-us/ai/seeing-ai
[4] https://www.blindsquare.com/

in the student's core mobility skills. P10 discussed using this with a client *"who was going to take his first independent bus ride from midtown Manhattan to Maryland"* and explained, *"I was able to see his progress. See how long it took him to stop, cross the street safely, get on the bus, and then he'd sit on the bus for about a half hour till the bus left. And I was able to track his progress all the way home."*. P10 finished up by saying, *"So that's one feature of tracking students, but they have to be very agreeable to it"*, and this last point is particularly important, as independence is at the heart of O&M and clients need to feel their privacy is not compromised.

The goal for many O&M clients is to be paired with a guide dog, but as P2 told us, *"Everything happens faster with a guide dog, and different skills for orientation are needed as a dog generally tracks around all the physical landmarks that cane travelers may use"*. This means that assessing a client's suitability and matching them with the right dog takes careful consideration. As P4 described it, *"They have to see your home environment, to see if it's suitable for a dog. They have you record videos to send in for application, and they have you measure your pace, so that they can match a dog with you"*. Like most O&M assessments these are currently based on qualitative observations, which can vary between instructors. When we showed the map prototype (Fig. 1a), P4 and P11 noted clear opportunities to improve this process because as P11 explained, *"To qualify for a guide dog you have to be out a set amount of time each week, you have to be out doing your route a set amount of time each week"*. Another opportunity that emerged from showing participants the map prompt was to use quantitative data to motivate clients by providing evidence of improvement. This was important because when clients first use a cane they will typically walk more slowly than before as they gain the cane skills. Improvement can then be slow and gradual as they become comfortable with a cane, and so keeping track of data such as pace would help confirm progress. P5 suggested such data may also offer a platform for reflecting on a client's travel range, e.g. progression may mean expanding from initially having two regular routes to traveling independently much further on four or five routes. Additional suggestions prompted by our prototypes included, adding sensors to a cane so that instructors could monitor their client's technique and eye tracking to to monitor whether a client is distracted, e.g. by the movement of traffic.

5 DISCUSSION

In this section we discuss possible opportunities for future HCI research and design identified by our inquiry. Our objective is to highlight practices that are already starting to emerge, and build on these to highlight areas for inquiry where HCI and CSCW researchers might usefully contribute through design or analysis, rather than present proposals for new approaches to O&M practice. This discussion does not consider finer implementation details, instead we link each opportunity back to our research findings, and then discuss them in light of prior HCI and CSCW research that can inform the direction of future work. First we focus on future opportunities associated with a possible 'physician's assistant' model for remote O&M instruction and assessment. We focus on this opportunity in most detail as it offers a response to the challenges of accessing O&M services in remote locations and in situations such as the recent COVID-19 restrictions, needs that motivated our investigation. Following this we also briefly outline three other design opportunities that were highlighted through our study: matching clients with guide dogs, highlighting progress, and closing the loop between route planning and monitoring travel. This is not meant as an exhaustive list, but highlights areas of possible need and reflects our interactions with participants.

5.1 Supporting a 'Physician's Assistant' Model of Remote Instruction and Assessment

Our research suggests that some O&M practitioners are taking steps towards incorporating elements of remote instruction and assessment into their practice models. Where they are doing so it is typically facilitated by a friend, family member, or other person from the client's support network

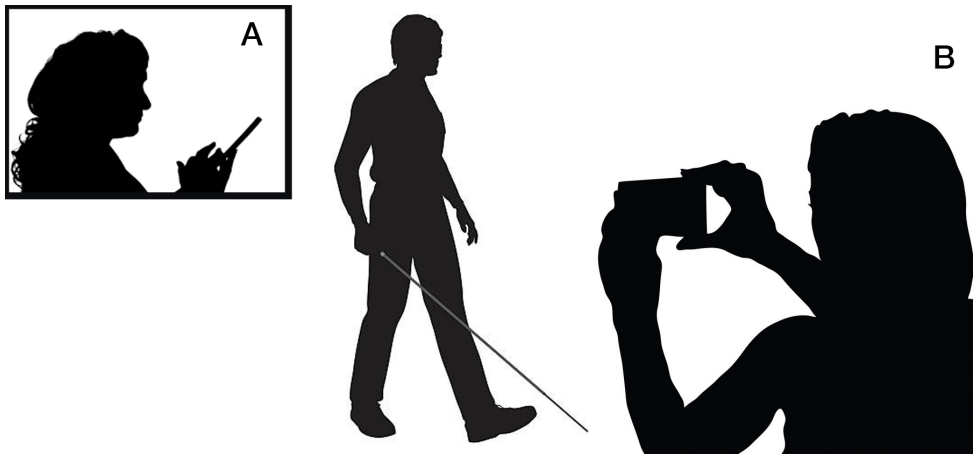


Fig. 2. In a Physician's Assistant model of remote O&M training or assessment, the specialist O&M practitioner (A) can remotely watch their client complete set practice tasks that are filmed by a member of the client's support network (B). Viewing may be synchronous or asynchronous, and the person filming may also act as a mediator for communication and safety.

acting as an in-situ partner for the O&M instructor (see Fig. 2). P1 described this as being similar to a 'physician's assistant' model. Future research might investigate these three-way interactions in the context of synchronous instruction where critical communication between the remote O&M instructor and their client must at times pass through the partner acting as an intermediary, or as asynchronous communication where an O&M instructor reviews recordings of their client completing 'homework'. While this may be a new challenge in the particular context of O&M instruction, there is a history of relevant HCI research to draw on, e.g. [48]. Additional HCI research that may be informative includes work on owning and controlling the point of view [61], and on video-mediated peer-support [92]. However, in recent years, remote practice has become increasingly familiar in rehabilitation medicine [36, 93, 121], and so HCI research investigating telemedicine in remote locations where resources are limited [20, 66], but also in contexts with more abundant resources [9] and which motivate ongoing activity [107], provides a rich source of examples to inform design in this context. To help structure remote assessment, future HCI research might also investigate how standardized protocols for O&M, such as VROOM (vision related outcomes in O&M) and OMO (O&M outcomes) [5] might be incorporated and facilitated by a remote support person.

5.1.1 Safely Supporting Remote Interactions. Our findings show that client safety is the primary consideration for O&M instructors. This should also be the case for HCI research into support for remote interactions. In Kamikubo et al's [57] investigation of support needs of remote visual assistants, such as BeMyEyes volunteers, remote video assistants and safety are both mentioned but no details are provided on how safety concerns might be identified, shared, and mitigated. This is typical, as to our knowledge there has been only limited prior HCI research into safety aspects of remote video interactions and how risk might be effectively assessed and mitigated. However, prior work does offer some initial pointers. For example, Lanir et al. [61] discuss how, in the context of task support, remote video assistance is often asymmetrical with the remote expert having greater knowledge of the problem or task while the person on the ground has a better overall view of the

[5] https://lildeverell.net/resources/vroom-and-omo-tools/

environment and situation. There are clear analogies here with the relationship an O&M instructor might have with an in-situ support person, and our participants discussed the dynamics in similar terms. Similarly, Toups and Kerne [115] studied remote communication and coordination, including safety concerns, in the context of firefighting, and argue that much important work is achieved implicitly and learned through experience. Future research should consider how digital tools might acknowledge and support these asymmetric interactions and scaffold experiential learning, perhaps through the additional support of automated risk identification, e.g. those associated with obstacles [63] or falls [124]; however, it is important to remain alert to additional communication complexities these may introduce.

5.1.2 Privacy and data sharing. Our inquiry also highlights how successful O&M instruction is built on trust between client and instructor. It is therefore important to be mindful that GPS enabled smartphones and remote video can raise concerns about privacy and data sharing, and about who has agency in these decisions. Mancini et al. [71] show the potential for tension between location-sharing technologies and social relationships due to perceived overreach; while Palen and Dourish suggest privacy management involves dynamically resolving tensions between and within people [80], and Troshynski, Lee, and Dourish [117] offer 'accountability of presence' as a way to strengthen privacy. Future HCI inquiry into remote O&M interactions will require ongoing negotiation about what is appropriate for each particular situation and how to make sure that agreements reached are adequately and properly informed. However, controls for flexibly adjusting these privacy and data sharing protocols might be based on a small set of guiding questions, such as: *who* is requesting; *why* they want location information; and *what* details are considered most useful [24].

5.2 Additional HCI Design Opportunities for Orientation & Mobility Instruction

In this section we highlight three additional opportunities for HCI research to support the work practices of O&M instructors. First we discuss support for matching clients with guide dogs, we then discuss opportunities to quantify progress, and show how HCI research might help close the loop between route planning and remotely monitoring travel progress. To close the section we highlight usability and accessibility challenges, and note the importance of existing artifact ecologies, providing pointers to prior research that can guide designers' response to the opportunities we identify.

5.2.1 Matching clients with guide dogs. The process of matching a guide dog to someone with impaired vision involves aligning a qualitative assessment of the person's walking pace and stride length with a trainer's assessment of the dog. However, there is often disagreement between specialists on how the client's walking should be categorized, which means that reaching agreement can take significant time and effort. Consumer wearables, such as those designed for runners [6], offer quantitative data that might help to augment assessments with standardized metrics. Here inquiry can be guided by recent clinical [120] and HCI [101] research into rehabilitation for neurological diseases, which shows that these sensors can provide detailed data on gait metrics such as stride length and cadence. Rehabilitation research has also shown how these sensors offer opportunities for remote longitudinal data collection [87]. This could support O&M instructors and their clients in collaboratively monitoring regular routes, to increase understanding of how ambulation varies in different situations and provide more detailed information for matching O&M clients with guide dogs. More speculatively, exploratory research has been undertaken into extracting stride parameters in wild animals using tracking collars [27]. Building on such studies, and on research

[6] www.runscribe.com

into animal-computer interaction [70], it may possible to gather equivalent gait and mobility data from service animals.

5.2.2 Quantifying progress towards goal attainment. O&M instructors typically reflect on progress towards agreed goals with clients during post-instruction discussion. Participants were excited that quantitative measures of pace or range of travel might augment this process. Future research might explore using consumer wearables to support these discussions by quantifying aspects of this progress. For example, O&M instructors might use anonymized comparative data from people considered similar to their client to provide evidence of typical or expected patterns of skill attainment. As the client progresses their own data might help strengthen confidence in the skills they attain and fine-tune expectations. Then as their capacity for independent travel grows, data can indicate the extent and range of places they now travel to, offering evidence of their flexibility and problem solving in taking alternative routes. Here research can be guided by prior HCI inquiry into using wearables to track and motivate fitness [35, 78], sports training [114, 118], and rehabilitation practices [7, 106].

5.2.3 Closing the loop between collaborative route planning and monitoring travel progress. Our research indicates that route planning and other collaborative rehearsal activities using digital platforms are an important emerging part of O&M instruction. Because of this, satellite and street views offered by tools such as Google maps can support an instructor in first identifying travel routes with their clients and then rehearsing how they might be completed. In this way an O&M instructor might identify locations where a client could experience additional challenges and then collaboratively prepare and rehearse effective mitigation options. Future research might investigate how this could be integrated with wider efforts to identify the accessibility issues that impact many different populations. For example, in prior HCI research, Guy and Troung [44] describe how a micro-task approach can be applied to gathering information about intersections using street view; Hara, Le and Froelich [46], and Saha et al. [95] show how the identification of street-level obstructions and accessibility problems might be eased and scaled-up through crowd-sourcing; and Miranda et al. [76] show how similar activities might be supported using visual analytics. Having identified these potential hazards and challenges, researchers might investigate how commonly used mapping and GPS apps can provide a rehearsal platform, e.g. by instructors and clients collaboratively inserting markers for obstructions and potential O&M challenges as they rehearse a route, and by including instructors' mitigation tips that can be triggered at these markers. Here guidance can be found in research into 3D printed tactile maps, which have been shown to help people with low vision to build mental maps [49, 50], and in Wu and Munteanu [124] work with older adults around sensor-based risk assessments.

Another emerging practice in O&M instruction is the use of assistive maps and GPS apps when travelling. Future research might investigate extending this to offer in-situ awareness and remote interactions between O&M instructors and their clients. In an asynchronous context this might include enabling the client to access pre-recorded tips and instruction linked to markers. Alternatively location and situation information might be sent to the instructor so they can support any necessary assistance at these pre-identified pinch points. This links the final part of the loop between route planning, rehearsing, and monitoring travel. We saw from P10 how tools such as Apple's Find My can be used by O&M instructors to monitor a client's travel progress as they make independent journeys. In future situations instructors might be forewarned as their clients approach locations identified with O&M markers. Here they might also be provided with details of the particular challenge to be faced so that they can share effective mitigation strategies if needed, and remind the client of actions they had previously rehearsed. Closing this loop may also help facilitate shared reflection about different challenges and how they were overcome, e.g. where

travel was obstructed or significantly slowed. This is significant because reflection on learning was something participants consistently brought up during interviews. Finally, closing this loop may help facilitate remote instruction for experienced independent travelers who are seeking help with a new route or are faced with construction work that impedes their normal travel, offering a quicker alternative to waiting for an in-person appointment with an instructor.

5.2.4 Accessibility and usability considerations. Unsurprisingly, our research indicates that O&M instructors and their clients represent diverse groups. When approaching the opportunities we have identified, researchers and designers should also consider accessibility and usability, not least because an aging population is one of the key factors motivating increased demand for O&M services. In addition to designing with accessibility for people with visual impairments foregrounded, future research should also remain mindful of factors associated with accessibility for older users, e.g. [75, 97, 105]. Even as demographics shift, and a larger proportion of the population that is considered 'older' includes long term users of digital technologies [82], there will be people who vary in confidence with and enthusiasm for digital technologies. Because of this, designs should support a number of different paths and styles, and thought should be given to possible implications for adoption [65]. Similarly, where future tools include representations of quantitative data, accessible and inclusive 'visualization' [62, 72] becomes an important challenge. Here some guidance is offered by Kim et al. [59], who offer a design space for accessible visualization, and Choi et al. [22] who suggest a process pipeline for visual translation. However, we also suggest that future HCI research is guided by the experiences O&M instructors and their clients may already have with tactile maps [119] and braille [85], and on recent research into adding interactivity [81] or 3D printing [49] to these. Navigating these concerns successfully will help in avoiding the discrepancy between design recommendations based on user research and design strategies employed in artifact creation [60] and help avoid well meaning 'parachute research' [67].

5.2.5 Sensitivity to existing use of digital tools. Our research highlights the existing roles digital technologies play in O&M instructors' teaching practice and in their clients' everyday lives, and so future HCI research and design should also be sensitive to existing and dynamic personal [13, 53] and community [14, 68] artifact ecologies. Rather than attempt to replicate different functionalities and bringing them into a single tool for O&M, there may be opportunities to encourage APIs that support integrating different tools into a consistent experience. For example, tools that utilize the Google maps API to enable O&M instructors to expand route planning and augment existing markers with tips for overcome particular mobility challenges. Hamm et al. [45] note how similar approaches that build on existing data sources and APIs are important to effective development and maintenance of civic tech. When thinking about these considerations, researchers can draw on CSCW work on design and infrastructuring sustainable HCI interventions, e.g. [86].

5.3 Limitations

We identify three main limitations that should be acknowledged with regards to the research presented in this paper. First, in this study the number of O&M specialists we interviewed was limited to eleven, and given the highly individualized nature of O&M instruction practice, this likely reflects an incomplete perspective on the current use and potential future roles of digital technologies in O&M work. Second, our focus in this research is on the digital tools used to support the work practices of specialists giving O&M instruction. Because of this, our participants were drawn from among experienced specialist O&M practitioners, rather than the wider population of people who are blind or have low-vision that may make up their clientele. However, it is clearly difficult to disentangle the needs of O&M instructors from those of the clients they serve. Because of this, the perspectives of O&M clients with diverse visual impairments should be considered a

necessary and important addition to this work that would inform both analysis and design. Third, the design prompts represent a limited selection of possible digital technologies that might support the work practices of O&M instructors. Other choices could have been made and we acknowledge that our choices have a likely priming effect on subsequent conversations. Future research should consider alternative prompts that might highlight different needs and opportunities.

6 CONCLUSION

In this paper we explore the role of digital technologies in supporting the work practices of Orientation and Mobility (O&M) specialists, who instruct people with low vision in concepts, skills, and techniques for safe and independent travel. Based on survey data and semi-structured interviews with eleven experienced O&M instructors, we identify multiple design opportunities for HCI research. These include: (1) supporting a 'physician's assistant' model of remote O&M instruction and assessment; (2) matching clients with guide dogs; (3) highlighting progress towards goals; and (4) planning routes and monitoring travel progress. O&M instruction is facing increasing demand from an aging population, but to date has received only limited attention in CSCW and HCI research. As a result little is known about the possible design opportunities and challenges that this domain presents. This study, which helps our understanding of the challenges O&M instructors face, their current workaround solutions, and the opportunities offered by new digital technologies, highlights the potential for HCI to make a substantial impact in supporting the important work of professionals that serve people with low vision.

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A SURVEY AND INTERVIEW QUESTIONS

A.1 Survey Questions

(1) Your Name:
(2) Please describe your current role, and your background in O&M practice or research.
(3) Describe some of the key challenges facing contemporary O&M practice and practitioners?
(4) Can you identify possible solutions to these challenges, or opportunities to progress O&M practice towards a solution?
(5) Can you describe some of the goals your clients want to achieve through O&M training?
(6) Please tell us about the outcome measures you report to track a client's success.
(7) How important are characterizations of overall mobility, and specific metrics such as gait speed, in measuring O&M success?
(8) Do you see a role for quantitative data tools, or other digital technologies, in collecting evidence for contemporary O&M practice? (Please provide details)
(9) Please tell us your own current vision status (if you are comfortable doing so)
(10) Would you be willing to talk to one of our researchers in more depth about these subjects?

A.2 Interview Topics

(1) Introduction and background:
- I'd like to start by asking you to introduce yourself and talk a little about your background. How long you have been working in Orientation and Mobility instruction? How did you got into O&M? What is your current position?
- What do you find most rewarding and most challenging about your role?
- I'd now like to move on to your clients and your practice. How many clients do you work with at a given time? And how do they get referred to you?
- What is the age-range of your clients? And the severity of their visual impairments? How likely is it that your clients will have other issues that impact on their mobility? E.g. reduced motor or cognitive capabilities?

(2) Pre-assessment of client needs before training:
- I'd like to talk a little about what happens prior to training. How do you currently carry out pre-assessment of clients' situation and needs, to customize training programs?
- In an ideal world, how would you improve this process?

(3) Assessment outside of client training sessions:
- I'd like to continue by understanding what happens between training sessions. How important is it for you to get a picture of your clients' mobility, and any issues they may have, outside of regular training sessions?
- How do you currently get this information?
- And what other information might be helpful in building this picture?

(4) Client assessment:
- I'd like to move on and discuss how you assess client progress.
- How do you identify and characterize areas of O&M training that clients have difficulty with?
- To what extent are your assessments of client's progress based on a normative comparison?
- To what extent do clients' self-assessments play a role in evaluating progress?
- How are these reports shared?
- What measurements do you currently record during O&M training or assessment?
- Do you base your assessments on structured evaluation activities e.g. complete this test course, or ongoing performance in natural settings?
- To what extent do quantifiable measures play a role in your client assessments?
- How do you currently collect data?
- In an ideal world, are there additional data you would have access to?

(5) Remote O&M Assessment and Training:
- I'm interested in your thoughts and experiences around remote instruction and assessment
- Have you had any experiences with remote assessment or remote training?
- Is it something you think is or might be appropriate?
- Are there circumstances that you think are more or less appropriate for remote assessment? Can you describe why?
- Similarly are there circumstances where remote instruction is more or less appropriate? Can you explain why?

(6) Digital Technologies:
- I'm also interested in your thoughts and experiences about using digital technologies to support you O&M practice, can you talk a little on this?
- Do cell phones or other digital assistive technologies play a role in your instruction? Or in your assessment of clients' progress and skills attainment?

- How do you decide when this is appropriate?
- Has using these technologies changed your relationship with clients in any way?

(7) Design Prompts:
- I'm now going to share a screen mock-up, which I'd like to use as a prompt for sharing thoughts and ideas. This screen represents a map of a client's possible practice route. The colors on the path can represent pace, for example.
- I'm also going to share a couple of videos that I'd also like to use as a prompt for thoughts and ideas.

(8) Wrapping Up:
- Thank you for your time this has been extremely helpful. I'd like to close up by asking a couple more questions.
- Do you see any low hanging fruit for digital tools that might support O&M specialists' work?
- Is there anything else you'd like to share about your O&M practice?

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