UNIVERSITY OF CALGARY

Designing Remote Collaboration Technologies for Wilderness Search and Rescue

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF DOCTOR OF PHILOSOPHY

GRADUATE PROGRAM IN COMPUTER SCIENCE

CALGARY, ALBERTA

JUNE, 2021

ABSTRACT

Wilderness search and rescue (WSAR) is the search for and extraction of one or more lost people (e.g., hikers, skiers) from a wilderness area. WSAR is time-critical, and even with current technologies, workers still face challenges in effective remote collaboration, information sharing, and awareness. The overarching goal of this dissertation is to understand how user interfaces can be designed to better support WSAR distributed collaboration.

I approach this first by understanding how WSAR workers collaborate remotely using today's technologies. In the first phase of my research, I ran an investigative study in which I interviewed WSAR workers and observed a mock WSAR response. My findings demonstrate that the main goal of a system for WSAR distributed collaboration should be to help workers construct and maintain a shared mental model, but there are unique challenges to doing this when scattered and moving around the wilderness.

Following this, I designed a prototype of a system for WSAR commanders. This system aims to provide commanders with more implicit awareness of events in the field and the experiences of field teams. It does this through (1) body cameras worn by field teams, streaming photos periodically to the command post; and (2) aggregating existing information channels together into one interface, allowing commanders to explore this information together as part of a bigger picture.

I then evaluated this system through a remote user study. I found that the awareness provided by body-camera footage could give commanders additional confidence and

comfort while reducing the need for explicit communications with field teams. However, it could also shift the burden of responsibility toward commanders.

Overall, this work contributes the following: (1) an understanding of WSAR remote collaboration practices; (2) the design of an interface for providing commanders awareness of events in the field; (3) a method for studying WSAR user-interface technologies remotely through simulated scenarios; and (4) an understanding of the potential opportunities and challenges of new information streams and communication modalities in WSAR. Beyond WSAR, this work contributes more broadly to our understanding of how to design remote collaboration technologies for serious team-based activities in large outdoor environments.

PUBLICATIONS AND RESEARCH ACKNOWLEDGEMENTS

The following publications have resulted from or are related to this dissertation work, and materials, ideas, and figures have appeared previously in them:

- **Jones, B.**, Tang, A., Neustaedter, C., Antle, A.N., and McLaren, E.S. (2020). Designing Technology for Shared Communication and Awareness in Wilderness Search and Rescue. In McCrickard, S., Jones, M., and Stelter, T. (Eds.), *HCI Outdoors: Theory, Design, Methods and Applications*, Springer.
- **Jones, B.**, Tang, A., and Neustaedter, C. (2020). Remote Communication in Wilderness Search and Rescue: Implications for the Design of Emergency Distributed-Collaboration Tools for Network-Sparse Environments. In *Proceedings of the ACM on Human-Computer Interaction, 4 (GROUP)*, ACM.
- **Jones, B.**, Tang, A., and Neustaedter, C. (2019). Drones for Remote Collaboration in Wilderness Search and Rescue. In *iHDI: International workshop on Human-Drone Interaction (CHI 2019 Workshop)*.
- **Jones, B.**, Tang, A., Neustaedter, C., Antle, A.N., and McLaren, E.S. (2018). Designing a Tangible Interface for Manager Awareness in Wilderness Search and Rescue. In *Companion of the 2018 ACM Conference on Computer Supported Cooperative Work and Social Computing (CSCW 2018)*, ACM, 161–164. (Acceptance rate: 28% – 1847/6682)

- **Jones, B.** (2018). Designing for Distributed Collaboration in Wilderness Search and Rescue. In *Companion of the 2018 ACM Conference on Computer Supported Cooperative Work and Social Computing (CSCW 2018; Doctoral Colloquium)*, ACM, 77–80.

- **Jones, B.**, Tang, A., and Neustaedter, C. (2018). Designing Outdoor Remote Communication Tools for Serious Collaborative Activities. In *HCI Outdoors: A CHI 2018 Workshop on Understanding Human-Computer Interaction in the Outdoors*.

The following article resulting from this dissertation work is, at the time of writing, in submission to the Association for Computing Machinery (ACM) Conference on Computer-Supported Cooperative Work and Social Computing (CSCW) and the Proceedings of the ACM on Human-Computer Interaction (PACMHCI) journal:

- **Jones, B.**, Tang, A., and Neustaedter, C. RescueCASTR: Exploring Photos and Live Streaming to Support Contextual Awareness in the Wilderness Search and Rescue Command Post. In submission to *ACM Conference on Computer-Supported Cooperative Work and Social Computing (CSCW)*.

The work done for this dissertation involves collaborations with other researchers, including fellow student **Elgin Skye-McLaren**, collaborator **Dr. Alissa N. Antle**, and my supervisors **Dr. Anthony Tang**, **Dr. Carman Neustaedter**, and **Dr. Ehud Sharlin**. While this is the case, this dissertation serves as an account of my personal perspective of this collaborative work, and thus I use the first-person singular pronoun (*I*, *my*, etc.) throughout this dissertation in reference to the work completed for it.

ACKNOWLEDGEMENTS

I owe a debt of gratitude to many amazing people who have supported me through my journey toward a PhD. Without their help and support, I would not have been able to 'search and rescue' my dissertation.

I would like to thank my supervisory committee: Ehud Sharlin, Anthony (Tony) Tang, Carman Neustaedter, and Wesley (Wes) Willett. Tony, thank you for taking me on as your PhD student, for putting up with another four years of me, and for supporting me and believing in me during both my ups and downs. It has been a pleasure working with you, and I am incredibly lucky to have met you and joined your lab as an undergrad way back in 2012. You shaped me into the researcher I am today, and I will continue to see you as my mentor. Carman, thank you for welcoming me into your lab at Simon Fraser University (SFU), and for your tremendously helpful guidance throughout my PhD. Your motivation, patience, guidance, and friendship helped me grow as a researcher. Ehud, thank you for joining my supervisory committee, supporting me, providing me much needed guidance, and becoming my primary supervisor after Tony moved to the University of Toronto. Wes, thank you for your amazing feedback and interesting/insightful discussions about my work.

I would also like to thank my examination committee members, Ryo Suzuki and Bryan Semaan, for taking the time to read and review my dissertation.

I thank the Natural Sciences and Engineering Research Council of Canada (NSERC), Alberta Innovates Technology Futures (AITF), and the University of Calgary for funding and supporting my dissertation research. I also give many thanks to the British Columbia Search and Rescue Association (BCSARA), SAR Alberta, and the numerous search and rescue agencies and members from British Columbia and Alberta, Canada whom I have been in contact with for their ideas and support of this work.

Thank you Lev (Leo) Poretski, Ava Lew, Sydney Pratte, Punyashlok Dash, Chelsea Mills, and Hanieh Shakeri for proofreading this dissertation and making it much more pleasant to read.

I also have a number of friends and colleagues to thank for cheering me on and supporting me through this journey. To my fellow cLab colleagues: Yasamin Heshmat, Lillian Yang, Samarth Singhal, Rui Pan, Azadeh Forghani, Carolyn Pang, Punyashlok Dash, Dongqi Han, Stephanie Wong, Nafiz Khan, Xiaoxuan (Anty) Xiong, Hanieh Shakeri, and Chelsea Mills. Thank you for welcoming me into your lab, having insightful conversations with me, collaborating on fun research projects together, hanging out on hikes and snowshoeing adventures, going out to restaurants, movies, PNE, and fireworks, and for our travels together to conferences. Each and every day, I looked forward to seeing you in the lab and working with you all.

To my other SFU colleagues, including (but certainly not limited to): Frederico Machuca, Victor Cheung, Alex Kitson, Shubhra Sarker, Mayra Barrera Machuca, Aldo Barrera Machuca, Elgin-Skye McLaren, Ivan Aguilar, Reese Muntean, Uddipana Baishya, Matin Lotfaliei, Ofir Sadka, Boxiao Gong, Aynur Kadir, Amy Chen, Doenja Oogjes, and Ann Chou. Thank you all for your support and friendships throughout my PhD.

To my fellow RICELab and iLab colleagues (from Calgary, Toronto, and beyond): Jiannan Li, Kody Dillman, Teddy Seyed, Bon Adriel Aseniero, Martin Fieck, Terrance Mok, Sydney Pratte, Karthik Mahedevan, Ava Lew, Audrey Labrie, Lev (Leo) Poretski, Ellie Sanoubari, Kurtis Danyluk, and Sasha Ivanov. Although I could not spend a lot of in-person time with you during my PhD, I still felt your presence and your support, especially toward the end of my PhD journey, when COVID-19 and `#WFH` brought us closer to each other through regular Zoom meetings.

I am incredibly grateful to have completed an internship at Microsoft Research Cambridge during my PhD. Thank you Sean Rintel for giving me this amazing opportunity, for being a wonderful mentor, and for connecting me with many amazing people at Microsoft. To my collaborators at Microsoft Research, including (but certainly not limited to): Priscilla Wong, Banu Saatçi, James Scott, Abigail Sellen, and Kenton O'Hara. Thank you for the opportunity to work with you all, and for making my internship experience more incredible.

Lastly, and above all, I thank my partner, Yaying (Sunny) Zhang, and my family for their tremendous support, love, and sacrifices for me. To Sunny, thank you for always being there for me, lifting me up, cheering me on, and listening to me talk, complain, and share random thoughts about my research. To my mom, Cathy, and my dad, Jeff: thank you for being supportive of me, no matter what direction I take in life, and for helping me become the person I am today. To my brother, Cory, and my sister, Becca: thank you for always being there for me, and for your much-valued advice.

To my mom, Cathy, and my dad, Jeff. Thank you for your unconditional love and sacrifices for me throughout the years. This dissertation is just as much yours as it is mine. To my brother, Cory, and my sister, Becca. Thank you for always being there for me, growing up with me, and supporting me in my ups and downs.

To my love and my best friend, Yaying (Sunny) Zhang. Thank you for sharing this adventure with me, for lifting me up, for celebrating with me when things are great, for giving me strength when I'm struggling, for listening to me complain, and for being the absolute best. There's no other person I'd rather spend COVID quarantine with than you. I'm so lucky to have you in my life. ♥ 你最好的，我爱你。

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INTRODUCTION

When a hiker gets lost in the woods or a skier does not return home from the mountain, a search crew is often called to find the missing person and bring them out of the wilderness safely. Wilderness search and rescue (wilderness SAR, or WSAR) involves the search for and extraction of one or more lost people (e.g., hikers, skiers) from a wilderness area. WSAR is a time-critical operation that requires careful communication and collaboration between many workers who are spread out in various locations, including at a command post (Figure 1, left) and in the field (Figure 1, right).

In a typical Canadian WSAR scenario, an agency from a nearby community is called to respond to a report of a missing person [58, 59] (often called the subject of the search). The SAR manager on duty for the agency sends a callout to volunteer members of the agency to meet at a specific location near the search area. When the members arrive, they form one or more field teams that search assigned parts of the search area. The manager and their management team work from a command post (a mobile-office trailer parked near the search area) in advance of the members' arrivals. Here, they plan specific search assignments (e.g., which areas to search, which search techniques to use, etc.) and give assignments based on the members available and their skills and backgrounds. Search plans are drawn up based on the information the agency has on hand about the subject,

Figure 1: WSAR involves careful communication, coordination, and information sharing between managers at a command post (left) and searchers in the field (right).

such as their last know location, their direction of travel, and other knowledge about their behaviour. Probability maps are created based on this information using statistics and years-worth of data describing how lost people typically behave in the wilderness [67]. The Command team is responsible for coordinating a large number of people, keeping track of vast amounts of information, and using that information to construct future plans of action.

Field teams traverse assigned locations, searching for the lost subject(s) through careful listening and observation. Search techniques can range from a precise search, in which a smaller area is covered in a lot of depth, to a broader search, in which a larger area is covered in a short amount of time but with less precision. Workers are specially trained in navigating tough environments such as rapid river crossings, steep mountain climbs, and deep snow. Field teams report to Command, via two-way radio communications, any information that may be important in figuring out where the subject is (e.g., footprints, objects left behind). Lastly, if a team finds the subject, they report this back to Command via the radio and begin the process of safely extracting them and moving them to safety.

In a WSAR operation, the 'workspace' is large. Workers are scattered across a geographic environment spanning an area of several hundred to several thousand square kilometres, and are required to collaborate and share information in relation to that. Much of this information is location-based (e.g., a WSAR manager tells a team of field workers which path they need to take, which spots they need to search carefully in) or visual-based (e.g., 'the lost person was last spotted on a path that forks, beside a tall evergreen tree near an icy lake'). Given the complexity of relaying these types of information verbally, new communication modalities and remote-collaboration technologies such as video communication could have potential to aid WSAR workers in sharing crucial information while collaborating to find the lost person. These kinds of technologies have been studied a lot in research in Human-Computer Interaction (HCI) and Computer-Supported Cooperative Work (CSCW), including for activities such as firefighting [63, 107], avalanche rescue [25, 26], and crisis response [3, 7, 17, 18, 105, 108]. However, HCI and CSCW research has yet to explore collaborative work in WSAR or the design of remote-collaboration technologies for WSAR.

Given the critical nature of WSAR, it is essential to understand, in addition to the opportunities new technologies could bring, the potential challenges they could introduce and important design tradeoffs that should be considered when designing novel remote-communication and distributed-collaboration technologies for WSAR. It is also crucial to understand the current collaborative practices of WSAR, and the realities of the situations they face.

The goal of this dissertation is to advance understanding of how to design and build technologies to better support distributed collaboration in WSAR, particularly between field teams scattered around a large geographic environment and a Command team stationed at a command post. I focus on this challenge through the lenses of HCI, CSCW,

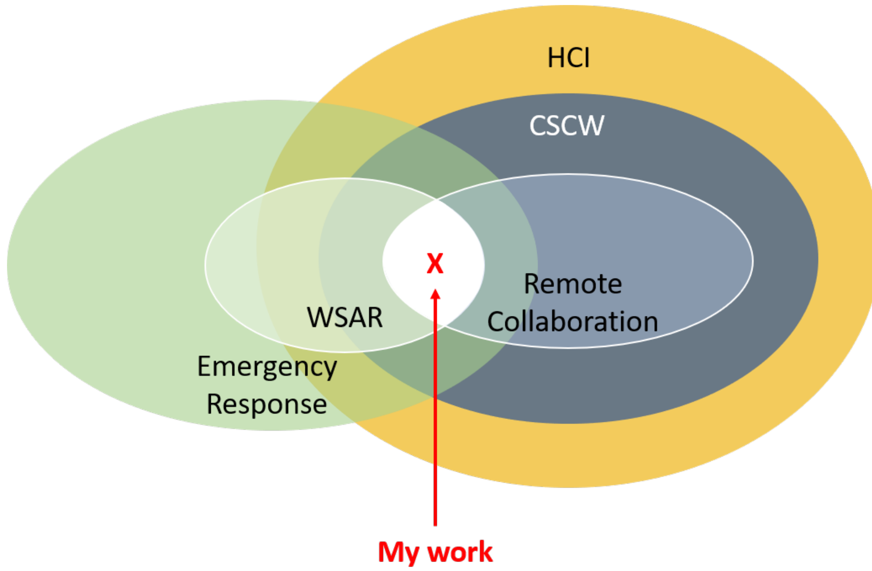

Figure 2: Illustration of the scope of my PhD dissertation work.

and user-experience (UX) design. While WSAR is the main focus of my dissertation, findings from this work could also be potentially applied to other emergency domains in which responders travel large distances (e.g., several kilometres) over long periods of time (e.g., several hours) over large geographic areas (e.g., several hundred to several thousand square kilometres in area), where understanding and awareness of conditions 'on the ground' are crucial. Such domains could include disaster response, wildfire response, and other types of SAR such as urban and combat SAR. My work is primarily focused on the search phase of WSAR operations, where multiple teams are deployed in the wilderness to cover a large search area looking for a lost person. Despite the related literature, we do not know what challenges WSAR workers face as a result of the wilderness and the large geographic distances they have to cover.

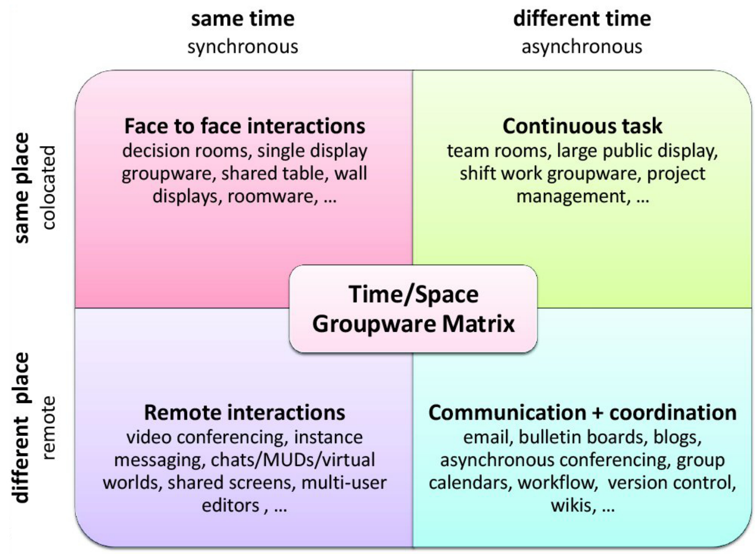

Figure 3: The CSCW Matrix, or time-space groupware matrix, conceptualized by Johansen [52]. Illustration is from [19] and in the public domain.

1.1 RESEARCH CONTEXT

My research lies at the intersection of HCI, CSCW, and emergency response, as illustrated in Figure 2. HCI is the study of how people use and interact with computer interfaces. CSCW is the study of how people interact with each other and collaborate on work and non-work activities through the use of computer interfaces. There is overlap between the fields of HCI and CSCW, as a subset of CSCW is concerned with how people interact with machine interfaces in order to achieve and/or support collaboration with other people, as well as with the design of user experiences and interfaces to support people interacting with each other on collaborative activities.

One of the central concepts of CSCW is the time-space groupware matrix (Figure 3) introduced by Johansen [52]. This 2x2 matrix conceptualizes contexts in which collaborative activities may fall under and in which CSCW systems may be designed to support. Each cell describes (1) whether collaborators are working synchronously (i.e., at the same time) or asynchronously (i.e., at different times), and (2) whether collaborators are co-located (i.e., in the same location) or remote (i.e., in different locations). WSAR involves various collaborative activities that fall under each of the four cells in the matrix. For example, face-to-face collaborations between workers at Command, as well as between members of a field team, fall under the Same-Place/Same-Time context. Remote communications over the radio between Command and a field team fall under the Same-Time/Different-Place context. A field team sending a photo or text message to Command from the field, or collecting some information to bring back to Command later, falls under the Different-Time/Different-Place context. Lastly, a WSAR manager taking detailed notes to be used by another manager later in the operation falls under the Different-Time/Same-Place context. The focus of this dissertation is primarily on Different-Place/Same-Time and Different-Place/Different-Time contexts, looking at synchronous and asynchronous remote collaboration between the command post and field teams.

1.2 RESEARCH GOALS

This dissertation focuses on addressing the following research problem: *"We do not know how technologies should be designed to support rich forms of remote communication and information sharing between the Command team and field teams in WSAR."* I approach this problem in three stages, each focusing on varying aspects of designing to support richer communication and information sharing in WSAR. In the first stage, I focus on understanding, through the lens of CSCW theory, how WSAR Command and field workers collaborate and share information remotely today, using existing technologies. In the second stage, I apply that knowledge to explore how we can use new and emerging technologies and communication mediums to make remote communication and information sharing between Command and field teams more effective. In the third stage, I seek to understand how new communication technologies and modalities could affect WSAR collaborative practices, again through the lens of CSCW theory.

As is evident from the paragraph above, each stage of my research focuses on a particular research problem:

- **Research Problem 1: We have a limited understanding of the challenges that WSAR workers face in remote communication and distributed collaboration.** This research explores challenges that may not be experienced by ordinary people performing everyday activities outdoors (e.g., hiking, snowshoeing). In addition, WSAR workers are trained to handle extreme situations, and this work provides understanding of how they handle such situations. I addressed this research problem through an investigative study in which I interviewed WSAR workers and observed a full-day mock WSAR search response.

- **Research Problem 2: We have a limited understanding of how remote collaboration technologies should be designed to better support building and maintaining a shared mental model in WSAR.** To address this research problem, I applied the findings from the investigative study to derive a set of design opportunities and recommendations for tools to help WSAR commanders and field teams more effectively communicate and share information with each other remotely. From these recommendations, I designed and evaluated a prototype system that can help WSAR commanders build and maintain awareness of field teams and their activities.

- **Research Problem 3: We have a limited understanding of how new remote collaboration technologies could impact WSAR work practices, including how WSAR workers collaborate and maintain a shared mental model across distances.** Design of novel WSAR remote collaboration technologies must consider the conditions and difficulties that WSAR workers face and how they overcome these difficulties. Design must also consider WSAR work practices which have been developed over the course of at least several decades. While new technologies could introduce potential benefits to WSAR teams and workers, WSAR workers need to understand how they can (and should) use new technologies properly so that they receive the highest benefit from them. Through the evaluation of the prototype I built from addressing Research Problem 2, I uncover insights into how new technologies could impact WSAR collaborative practices.

1.2.1 *Overall Research Approach*

I took a multi-pronged approach to addressing these research problems. My first step was to better understand the domain of WSAR as well as the challenges that arise, from both the perspective of the field and the command post, when there are gaps in realtime communication. To do this, I ran a study where I interviewed WSAR volunteers and observed a full-day WSAR mock-search training activity. My findings demonstrate that the main goal of a system for WSAR distributed collaboration should be to help workers construct and maintain a shared mental model, and that there are three relevant design directions for pursuing this: (1) anticipate transitions between varying states of radio connectivity and make relevant information exchange available during moments when in an 'offline' state; (2) improve comprehension of a situation through providing new types of information in more useful formats; and (3) simplify and automate the process of collecting, sending, receiving, and viewing information.

Figure 4: The RescueCASTR Command interface, introduced in Chapter 4.

Following this investigative study, I designed a prototype of a system for the WSAR command post, called ***RescueCASTR***, or *Search and **Rescue C**ontextual **A**wareness **Str**eaming Platform* (Figure 4). This interface is designed to help Command keep track of field teams' progresses, actions, and communications in a large WSAR operation. The goal is to explore ways to bridge the perspectives of Command and the field through new technologies and information streams. For this work, I focused on the Command side; more specifically, on exploring ways to provide Command with more implicit awareness of events and conditions in the field and the experiences of the field teams, so their decision making can be better reflective of and empathetic toward the experiences and needs of the field teams. RescueCASTR does this by exploring the idea of sending teams out to the field with at least one of their members wearing a body camera that streams live video or sequential photos periodically (e.g., once every five seconds) to Command, allowing Command to see the footage live and explore past footage.

I then evaluated RescueCASTR through a remote user study with WSAR workers in Canada, to understand the potential opportunities that such a system could provide to WSAR commanders, including the potential for WSAR managers to use the system as part of their workflow in building and maintaining a mental model of the operation, as well as in projecting ahead and planning future decisions. From this study, I found that WSAR managers see video/picture streaming from wearable cameras as something that could be useful for them to provide contextual awareness of a team's progress and status, essentially acting as a bridge between the 'focus and context' [4] of other data channels. This awareness could provide additional confidence and comfort, as well as reduce the amount of explicit communication requests (e.g., radio checks) from Command to the teams, which could help teams focus more on their in-the-moment duties, as well as save time on Command's part, allowing them to put their focus toward other activities. SAR managers also pointed out that the camera footage could be useful for planning and reviewing activities, both during and after a response. However, the new capabilities afforded by body-camera streaming could also impact WSAR workers' traditional roles and responsibilities, shifting the burden of responsibility further away from field teams and more toward Command. For example, the body-camera streams could encourage Command to micromanage the teams, and make them responsible for acting on the knowledge contained in the footage, even if they are not watching all the time and even though field teams still have a better view of the situation.

Given that my dissertation work focuses on understanding the unique needs and challenges of a particular user group, and on exploring new technologies for addressing the needs of that user group, my research is qualitative and exploratory in nature.

Throughout my dissertation work, I employ qualitative research methods [23] such as *semi-structured interviews*, *observations*, and *think-aloud procedures* to reveal insights about how WSAR workers and teams use technology to collaborate, how certain technologies benefit or hinder them, and what are their needs as users. While these methods are not well-poised to measure how well a particular technology solution *performs* among certain users or in certain circumstances (as *quantitative methods* [22] are suited for), qualitative and exploratory methods can be useful in the early stages of the design process to reveal the *existence* of certain phenomena, to gain understanding of possible design directions. As WSAR remote collaboration has not been studied extensively in CSCW and HCI research, it is appropriate to take such approaches in my research.

1.3 CONTRIBUTIONS

My dissertation work provides the following contributions: (1) an understanding, through the lens of CSCW theory, of how WSAR workers use technology to collaborate and share information remotely during a search response, and the challenges they face in doing so; (2) insight on how technology can be designed to better support WSAR remote collaboration; (3) a prototype system to help WSAR commanders build and maintain awareness of field teams and their activities; and (4) insight on how WSAR work practices could be impacted by novel collaboration interfaces and new information-sharing modalities.

This work reflects on the CSCW theoretical concepts of team cognition, awareness, and shared mental models; and discusses the challenges of attaining and maintaining these in contexts related to WSAR, as well as design considerations for supporting these in such contexts. Beyond WSAR, the findings from this dissertation work could also apply to other collaborative command-and-control activities in which multiple teams or individuals need to move around a large environment and share information related to the environment. Such examples could include other emergency domains such as wildfire response, disaster response, or police work. Even beyond emergency response, command-and-control activities take place across a variety of contexts, including in the military, in control centres for infrastructure such as transit systems (e.g., [47]) and power plants, as well as during large-scale missions such as in space exploration (e.g., [89]). While not all contexts are the same (e.g., they vary in terms of the number of collaborators, the size of the workspace, and the time span of the activity), enhancing understanding via multiple contexts of different scales can benefit the design of user-interface technologies for command-and-control more broadly, and insights from one context can be adapted or scaled to other contexts. This is what I hope my dissertation will provide to the broader body of knowledge on command and control, through the specific context of WSAR.

1.4 OVERVIEW

This dissertation is structured as follows:

Chapter 2 covers relevant background literature from HCI and CSCW, including CSCW theory on teamwork, awareness, cognition, and shared mental models, remote-collaboration and video-communication interfaces, CSCW research on emergency and disaster-response domains, and past work in SAR, including search theory and HCI design solutions.

Chapter 3 describes the investigative study I conducted with WSAR workers in Canada to expand understanding, through the lens of CSCW theory, of how WSAR workers communicate, collaborate, and share information with each other remotely during a search response. This study consisted of two parts: (1) semi-structured interviews with WSAR workers, and (2) an observation of a day-long mock WSAR search response. This chapter also discusses design opportunities and recommendations for technologies that support remote information sharing between field teams and the Command team in WSAR, derived from the findings of the investigative study.

Chapter 4 introduces RescueCASTR, an interface designed to help Command better understand the activities of field teams and the situation in the field. I also describe the process leading to the design of RescueCASTR.

Chapter 5 describes the remote user study I ran with WSAR workers to evaluate the RescueCASTR prototype. Here, I discuss the study design, the study goals in relation to the research goals of this dissertation, and the study findings.

Chapter 6 discusses the important lessons and takeaways of this dissertation work, mainly derived from the findings of the studies in Chapters 3 and 5. This chapter also highlights this dissertation's contribution to theories on teamwork, awareness, and cognition in CSCW, and reflects on lessons learned from evaluating an interface for emergency response via a remote simulation-based user study.

Chapter 7 concludes this dissertation, and reviews the overall goals, contributions, and implications of this work.

2

BACKGROUND

In this chapter, I present background on topics that are relevant to my dissertation work. First, I will discuss key theoretical concepts in Computer-Supported Cooperative Work (CSCW) that my research relies on, including theories about teamwork, cognition, shared mental models, awareness, and collaborative coupling. I will also discuss how user-interface technologies can be designed to help teams better build and maintain these facets of collaboration. I will then share CSCW research in other emergency response settings, including disaster response, firefighting, and emergency call centres; and discuss the similarities and differences between these activities and wilderness search and rescue (WSAR). Later, I will cover interfaces designed to support remote collaboration, including video-conferencing and remote-instruction interfaces. Finally, I will present and discuss literature in search and rescue (SAR), including principles, theories, and techniques in SAR planning and operations, as well as technology solutions to some problem areas in urban SAR, WSAR, and avalanche rescue.

WSAR, especially large operations, requires structured teamwork, collaboration, and coordination across distances. Thus, it is important to understand CSCW theory on teamwork, awareness, cognition, and shared mental models in order to understand how to design technologies to effectively support these things in WSAR. In this section, I will cover important theories of team structures and collaborative work, relate them to what we already know about WSAR, and highlight the gaps in our existing knowledge that will be covered in my dissertation.

2.1.1 *Teams and Teamwork in WSAR*

A *team*, according to Salas et al. [93], is "a group of individuals working together toward a shared and valued goal, which will disband after the goal has been completed." In WSAR in Canada [58] and in much of the world, a *response team* consists of all of the individual WSAR workers responding to a single incident. It consists of the *Command* team and one or more *field teams* deployed to different spots in the search area. The Command team is made up of all of the members working at the command post, including the SAR manager, planners, communications officers, logistics personnel, and others helping oversee the operation. A field team consists of a team leader and up to seven members. A response team is created at the beginning of an incident and disbanded once the incident is resolved. In incidents that take place over longer periods of time (e.g., more than one day), individual members of the response team may change, as members can swap in and out to keep the operation going. A *WSAR agency*, in contrast to a response team, is a more permanent establishment, which is itself a team consisting of members that respond to incidents regularly, taking place within a defined area of jurisdiction (e.g., a provincial or national park, or a region surrounding a town or city), and sometimes providing mutual aid or assistance to other nearby agencies. Within a WSAR agency, members meet on a regular basis to train, practice, and review incidents together. Thus, a WSAR agency is a team entity that exists for a longer period of time (e.g., several years or decades), whereas a response team only exists for the response, which is usually at most a few days. Depending on the circumstances, a response team could consist of all of the members of a single WSAR agency, a subset of the members, or a subset of members across multiple WSAR agencies.

2.1.2 *Team Cognition*

Team cognition [36, 49] is the shared knowledge and awareness of team members, work processes, practices, tasks, and the workspace; and the ability to coordinate and act together based on that shared knowledge [36, 49]. It is essential for complex tasks in which large numbers of workers need to quickly share information, understand each other's actions and statuses, and coordinate their activities – e.g., in contexts such as air-traffic control rooms (e.g., [78]), metro-system coordination centres [47], space-shuttle mission-control centres [89], firefighting [107], and disaster response [104, 105].

Implicit communication (sometimes called *consequential communication*) happens when a message that is not specifically intended to be communication is sent or received. It is unintentional communication that happens as a result of one's actions, such as their use of or interactions with a tool or artifact [33]. For example, someone putting on their jacket and hiking boots communicates that they are about to go outside and on a hike. The act of putting on the jacket and boots is not intended to be communication, but it still communicates a message. This is in contrast to *explicit communication*, which is an act that is solely intended to be interpreted as communication [33]. Implicit communication is usually done through non-verbal actions, whereas explicit communication can happen through both verbal words (e.g., speech or text messages) and non-verbal actions (e.g., deictic referencing such as pointing or gesturing with one's head or body). Team cognition is supported by both explicit (e.g., [38, 41]) and implicit communications (e.g., [107]).

In team situations such as firefighting [38, 63, 107], there are a number of workers 'on the ground' responding to an emergency, communicating carefully with each other, and answering to an *Incident Commander* (the main person in charge of the incident response [34]) at a base (e.g., a command post or a fire engine) [58, 107]. Responders need to be highly trained in communicating [38, 58], coordinating [58, 107], and using the radio [38, 58]. Toups and Kerne [107] found that firefighters maintain team cognition by communicating in-person via words and non-verbal gestures, and seeing each other's actions and intentions. This is all in service of planning and guiding their actions as a collective. In large WSAR operations, while the members of each smaller sub-team (Command and each individual field team) are co-located, the response team as a whole is distributed, thus reducing opportunities for face-to-face interactions between the sub-teams. I explore how WSAR workers try to perform similar coordination actions as firefighters, but across distances. I also explore what role these actions play in the overall operation, and what opportunities exist for technology to provide this support in WSAR. To date, studies have not uncovered this knowledge.

Another context requiring high levels of team cognition is command and control – for example, metro-system control rooms [47], space-shuttle mission-control centres [89], and air-traffic control rooms [78]. Implicit (consequential) communication is common in these types of settings. Workers use a variety of senses, media, and techniques to coordinate their actions, keep track of important information, and conduct their duties properly and with as few errors as possible. These include acts of implicit communication such as listening to and observing one's colleagues' actions and seeing things in one's periphery, and acts of explicit communication such as reading, writing, talking with others, speaking-aloud one's actions, and passing sticky notes. These studies have shown that being able to constantly observe [47], hear [89], and read the intentions of [47] colleagues helps in proper planning and decision making for complex group activities requiring high amounts of focus, collaboration, and coordination. They are useful for collaborative activities that are *tightly coupled* (i.e., where team members rely on other team members to complete their work) [82, 95], but not as necessary during *loosely-coupled* activities (i.e., where team members are not as reliant on others to complete their work) [82, 95]. Activities within sub-teams (i.e., the Command team and individual field teams) in WSAR are tightly coupled, given team members' close co-located interactions with each other. Yet, because the field teams and Command are spread out and, more often than not, disconnected from each other [58], they have reduced opportunities to interact with each other through multiple forms of communication (e.g., explicit verbal, explicit non-verbal, implicit). Thus, the sub-teams operate semi-autonomously and do not necessarily know what the other teams have seen, nor how it relates to their situation. As a result, WSAR work practices are designed to have activities between sub-teams be loosely coupled [58]. There is a lack of understanding of how this style of coupling affects WSAR distributed collaboration overall, especially between field teams and Command. It is also worthwhile to explore how new technologies can introduce tighter coupling between field teams and Command through additional forms of communication, as well as what implications this could have on WSAR work practices.

Distributed cognition theory [49, 51, 92, 94] is an approach to understanding cognition not merely as something taking place within an individual, but also as a phenomenon taking place at the team level. The theory describes a team's overall cognitive system as being distributed, represented across artifacts, their representations, their placements around the workspace, and in the individual cognitive processes of the team's individual members. All of these things interact with each other over time to produce a combined cognitive system. It is the quality of these interactions, according to Weiser [109] and Cooke [20], that lead to strong team cognition. In particular, the use of artifacts to support team cognition has been highlighted in settings such as air-traffic control rooms, where workers use paper flight strips to represent and keep track of the flight plans of nearby aircraft [78], metro-system control rooms, where workers use timetables to keep track of and modify the schedules of different train routes [47], and emergency call and dispatch centres, where call takers enter information about a call on a text interface and pass the information along to a dispatcher [84]. These artifacts allow team members to transfer knowledge across space and time, to be used by the entire team and during the entire timeline and process of the collaborative activity,, rather than just by one or a subset of its members and during a brief moment in time. The use of artifacts can play a supplementary role in supporting team cognition, especially in cases where verbal, implicit, and explicit non-verbal communications may not be sufficient. In WSAR, given the limited communication channels in place between field teams and Command, it would be useful to understand how commanders and field workers use artifacts, such as paper forms or notes, to support shared cognition and understanding of one another's actions. I achieve this understanding through the study I present in Chapter 3.

2.1.3 *Shared Mental Models*

A *shared mental model* [13] is a shared and consistent understanding that collaborators maintain as they go about their work. It comes from people talking to one another and looking around to see what others are doing. Early research in CSCW promoted the idea that a shared mental model is important for large collaborative activities involving many people and resources, in particular because it helps maintain strong team cognition [8, 13, 80, 82]. In WSAR and other emergency domains, members generally go through the same training and use the same language and communication protocols while working together and passing along information [58, 59], although standards could vary slightly across jurisdictions. The *Incident Command System* (ICS) [14, 34, 46], now part of the US National Incident Management System (NIMS) [34, 50], is a standard emergency protocol developed and used extensively in emergency management over the last few decades around the world, and it is the central underpinning of how roles and tasks are assigned and how information flows in WSAR in Canada [58, 59]. ICS is a core part of the shared mental model of WSAR and other emergency domains, given that it helps emergency responders communicate and collaborate using shared language and protocols they agree on [9]. WSAR standards and protocols allow multiple agencies to use the same shared language when, for example, one needs to provide mutual aid to another person [58, 59]. In addition, ICS allows emergency responders from multiple domains (e.g., EMS, firefighters, police, etc.) to collaborate using a common language [34, 50].

2.1.4 *Awareness*

More recent research in CSCW has reflected on the concept of shared mental models and argued that they are not always necessary for successful collaboration during team activities, as collaborators do not necessarily need to have the exact same knowledge to complete a task together [15]. For example, if work is *loosely coupled* [95] and each team member is playing a distinct role or taking on a unique task (but each task and role builds up to form the larger activity), then each team member will have unique knowledge and a unique perspective. In this case, sharing knowledge may not always be beneficial, and in some cases if it is irrelevant knowledge, it may be distracting to the task at hand [15]. Rather, just having a shared sense of the team's goals and objectives and awareness and understanding of who on the team knows what and what everyone's capabilities are may be sufficient. As a result, it is also useful to understand other theories that can contribute to an understanding of how team collaboration can be successful. These include theories about awareness, including *team awareness* [15], *situation awareness* [31], and *workspace awareness* [44, 45].

Team awareness is one's awareness and understanding of the presence, activities, and characteristics of their team members, as well as the larger makeup of the team [15]. It requires understanding across four different facets of collaboration: common ground, communities of practice, social capital, and human development. Technologies used for WSAR communication and collaboration should help provide and maintain team awareness across these facets.

- *Common ground* is awareness of the status of the task at hand. Team members require knowledge of what other team members are doing, as well as of what aspects of the activity have been completed and/or are in progress. In WSAR, workers need to be aware of the search coverage area, the locations of fellow team members, the knowledge of fellow team members (e.g., what/whom they see), weather patterns, clues left behind by the subject(s), and features of the environment (e.g., terrain, paths, objects, bystanders) [58].

- *Communities of practice* refers to understanding collaborators' behaviours and acting and responding as a community (or as a team). In WSAR, due to the time-sensitivity of the situation, workers need to be able to act quickly and effectively as a team to cover as much ground as they can, as quickly as they can. WSAR members need to be able to effectively coordinate their field teams, and members of field teams need to be able to effectively cover the ground they are assigned [58].

- *Social capital* refers to collaborators' trusting of one another, and their perception that each is acting with the intent to serve the common goals of the group. In WSAR, team members cannot hesitate, because any hesitation by a team member, due to not trusting another team member's advice or instructions, puts the success of the task at risk [58].

- *Human development* refers to individuals' abilities to grow personally and professionally as a result of their collaborations with team members. In WSAR, team members may come from a variety of backgrounds and have a variety of initial skill sets, but through collaboration on search incidents, they may be able to pick up specialized skills from other teammates that they did not have before. Awareness of team members' strengths, weaknesses, and personal development is important for effective teamwork in WSAR [58].

Situation awareness (SA) is the ability to perceive and understand one's own current situation and use that understanding to make proper decisions and project one's future status [30, 31]. *Shared situation awareness* (SSA) is a team's shared understanding of the situation. According to Endsley et al. [32], SA can be broken down into three levels: (1) *perception* of the elements in the environment, (2) *comprehension* of the current situation, and (3) *projection* of future status. Achieving the first level is relatively easy, as it is not difficult to get everyone to experience or perceive the same thing. Achieving level two is more tricky though, as different collaborators may comprehend the same thing in different ways, depending on their skill levels or perspectives. Finally, level three is the most difficult to achieve, as predicting future status can require both a very high level of understanding and a lot of mental effort. Achieving each level requires attaining awareness in all of the preceding levels (i.e., level three cannot be achieved without first achieving levels one and two, and level two cannot be achieved without first achieving level one).

SA is particularly difficult to establish and maintain over distance [31, 32]. Given that rich levels of communication and information sharing are required to quickly and effectively perceive the current situation, it can be difficult simply to attain level-one SA over channels such as the radio, telephone, or text messaging, as these cannot transmit as much information as face-to-face interactions can. Some of the challenges relate to technical issues and limitations such as bandwidth and reception. However, even in situations where sufficient sight and sound can be transmitted to attain some degree of level-one SA (e.g., in a video call showing the entire workspace), it may not be enough to lead to collaborators having a common understanding of the situation. For example, collaborators might not process a visual representation of a workspace as a video image (e.g., a video call) or 2-dimensional map (e.g., a map of aircraft's positions in an airspace) as naturally or intuitively as they would process an understanding of the space through actually being there, thus leading to delayed comprehension and/or gaps in their understanding. Thus, enabling SSA across locations, time points, and perspectives is a common challenge to be addressed in the design of collaboration technologies for distributed teams. WSAR, as an activity distributed across locations, time, and perspectives, likely presents this challenge as well. However, there is a gap in our understanding of how WSAR workers attempt to establish and maintain SSA across distances through current work protocols, where they succeed, and what challenges they face in doing so. There is also a lack of understanding of how a lack of SSA affects WSAR collaboration, and what implications increased SSA could have on WSAR work practices. Achieving an understanding of these is crucial to knowing how to design technologies that help WSAR workers better achieve SSA.

Workspace awareness (WA) is an understanding of who is 'in' the workspace and what is happening and has happened within its temporal and physical bounds [45]. It is an understanding of who is and has been present in the 'workspace' (or activity at hand), what they are doing within it, what their contributions have been, and how the state of the workspace, including the artifacts and information within it, have changed [45]. WA focuses on questions about *'who?'* (e.g., who is and was in the workspace), *'what?'* (e.g., what were they doing, what did they intend to do), *'where?'* (e.g., where were they, where were they looking), *'when?'* (e.g., when did it happen), and *'how?'* (e.g., how did that operation happen). Collaborators attain knowledge about these through explicit verbal and non-verbal communications, implicit (consequential) communications [97], and feedthrough [28].

In WSAR, the 'workspace' consists of the search area and the command post, and its temporal bounds are from when the callout for the missing person is initiated to when the incident is resolved (after the lost person is found and extracted, or the search is called off) [58]. Thus, the workspace is large, often several hundred to several thousand square kilometres in area, spanning a time period of a few hours to several days. Given this size, team members must rely heavily on remote communications to support WA. In addition, for longer searches spanning several days, workers need to record and keep track of knowledge about past actions in the search, such as what areas have been covered and what clues have been found, and use that knowledge to plan and project ahead to the future (e.g., in determining what areas need to be searched next) [58, 59]. There is a gap in our understanding of how (and to what degree) WSAR workers use remote communication to maintain WA, and how technologies can be designed to help them better achieve this.

2.2 EMERGENCY AND DISASTER RESPONSE

In the aftermath of large-scale crisis events such as earthquakes, hurricanes, and mass shootings, a plethora of information about the crisis is often available on social-media channels such as Facebook, Twitter, and Reddit [104, 105, 111]. Social media can contain real-time on-the-ground information from those affected by the crisis, including victims, bystanders, and citizens providing help to the victims [104, 105]. Social media can also act as a network to connect those who need help to those who are able to provide help, such as those who want to donate supplies, food, water, or provide transportation or a place to sleep [104, 105]. Responders can make use this information to inform the decisions they make [104, 105, 111], and also route it to the proper recipients, in order to deploy needed responders (e.g., firefighters), community volunteers, and resources (e.g., food, water, bedding, etc.) in an efficient manner [104, 105]. All in all, social media has a strong potential to connect people distributed in various locations who want to help victims and share their resources. However, social media also contains a vast amount of information, some of which is unimportant, repetitive, hard to verify, difficult to sort through, and in some cases outright false [111]. Given that most of the information comes from everyday citizens, there is no guarantee of its quality. WSAR scenarios are similar in that there is information being collected on the ground by people who are distributed, the information is being dealt with by Command workers to make planning decisions, and command is trying to figure out how to route the right information to the right people. The main differences, however, are that in WSAR, the scale of the information is not as large, and it is often more trustworthy (e.g., WSAR workers are trained professionals, and they can be relied on to provide truthful information, at least more so than people on social media).

One major challenge in emergency situations is "how do you get the right *information* to the right *people* at the right *time*?" *Actionability* refers to the idea that certain information is relevant, or actionable, to a certain person depending on the role they play, the context they are in, and the time [111]. Information that is useful to some people in certain contexts and times may be useless to others, at different times, and/or in different contexts [111]. In WSAR, Command has a lot of information, mostly coming from field teams, but occasionally from external sources such as police, the victim's family, and/or weather agencies [58, 59]. This information is aggregated, processed, and made sense of over time. Command workers use the raw information to then process new information such as task assignments, paths to traverse, and probability charts (i.e., the probability that the lost subject will be found in a certain area) [58, 59, 67]. This information then needs to be passed on to the relevant workers in the field at the right time. Relevance in this case could depend on, for example, one's role, task assignment, skills, search strategy, and location in the field. To date, research has not explored how WSAR command workers determine which information is actionable to which people, how command workers pass on this information to the right people, and how this whole process can be improved and/or expedited. This is my focus.

2.3 REMOTE COLLABORATION AND VIDEO COMMUNICATION

The focus of my dissertation is on *remote collaboration* in WSAR. Remote collaboration can take place in a number of contexts. For example, previous work has explored remote collaboration in physical tasks (e.g., [35, 37, 39, 40, 57]) and in the outdoors (e.g., [53, 57, 60, 65, 106]). Researchers have looked at both one-on-one contexts, where two people are collaborating in two different locations (e.g., [48, 90]), and contexts involving more than two collaborators in more than two physical locations (e.g., [107]). My focus, studying WSAR workers, is on contexts involving multiple collaborators distributed across multiple outdoor locations (the field teams) and one indoor location (Command).

CSCW design solutions have explored video and pictures as a medium for remote collaboration and sharing information, including in emergency domains. Previous work has revealed value in emergency dispatchers and coordinators receiving information in the form of photos and videos from the ground and using them to aid in coordination and building a mental model [6, 74, 110]. Previous work has also explored the use of CCTV camera footage to aid coordinators in control centres (e.g., [47, 75, 76]). In both types of situations, collaborators found value in being able to see a visual picture of what was happening on the ground, and how their decisions from afar were affecting the situation on the ground. Video and pictures are especially useful in conjunction with other types of information such as audio (i.e., verbal) descriptions [6], written (text) reports [74], and maps [110].

While video and pictures can provide useful information, there are difficulties in making sure that they contain *actionable* [111] information. The difficulties usually centre around the challenge of camera work [57, 88, 90], which involves making sure the right visual information is communicated in the camera frame. Poor camera work can result in reduced awareness and thus reduced ability to take action [57]. Effective camera work is even more difficult to attain when the camera is mobile (i.e., the viewpoint is moving) [57]. In these types of situations, local users try to provide awareness to remote viewers through moving the camera to provide overview shots (e.g., as panning or zooming out to set the scene) and detail shots (e.g., close-up or 'centre-stage' shots to show objects of interest). The styles of camera work are similar to cinematic shots when people film videos. However, such shots do not always provide remote viewers with sufficient spatial awareness or understanding for the task at hand, and they are insufficient for tasks involving search and navigation [57]. Furthermore, it is difficult for the local user to handle the camera at the same time as they are engaged in a task [57].

This problem has also come up in emergency domains such as emergency (e.g., 9-1-1) video calling [84, 85, 100] and firefighting [63]. In emergency calling, concerns usually centre around whether the caller can provide sufficient camera views for the call taker and/or dispatcher to properly assess the situation [84, 100]. Given that it is usually best for the call taker to have control of the situation, the suggested approach is to give the call taker the ability to control the camera view, or to at least provide them with means to suggest what camera work the caller should perform [84, 100].

Other technologies exist that aim to address the challenge of providing 'good' camera views. Researchers and designers have proposed the use of 360° cameras (e.g., [61, 62, 106]), drones (e.g., [53, 64, 98]), and wearable movable cameras (e.g., [69, 70]), as well as adding contextual information (e.g., live map views, task progress bars, etc.) alongside video streams as a means of enhancing a remote viewer's understanding of what is happening in the space [65]. While these solutions can provide the remote user with more useful information and greater awareness, the additional capabilities provided by them have also presented challenges. These include being unable to easily comprehend large amounts of visual information in the case of 360° videos [106], difficulties matching information from multiple camera views together [53], or the challenge of needing to focus on controlling the camera while also contributing to the activity at hand [53].

Researchers have also explored giving the remote user greater control and extra communicative abilities. Solutions include on-screen annotations (e.g., [35, 37, 39, 40, 60, 103]) and deictic referencing from a 'god-like' perspective [103]. Such gesturing or annotation techniques could be potentially useful in WSAR, as they could allow a WSAR manager in a command post to help guide a field team through a difficult-to-traverse area, or allow them to communicate other location-based information (e.g., exploring where to land a helicopter in a helicopter-rescue scenario).

Privacy concerns also arise when using cameras to capture footage in public [11, 57, 90, 101]. Such concerns have arisen in studies involving 9-1-1 video calling [84, 100] and firefighters [85]. This issue usually centres around capturing bystanders on video inadvertently; though in such emergency domains, there are also concerns around capturing video of deceased people. In addition, there is also the issue of liability, and potentially capturing a worker making mistakes on camera. These same issues could certainly occur in WSAR as well. Researchers have proposed solutions that involve blurring or masking the identities of unconsenting bystanders [10]. Such an approach could be valuable in emergency domains such as WSAR. For my work, I am interested in how WSAR workers might approach privacy issues, and how they should be addressed within the context of WSAR work practices.

SAR in various contexts (e.g., urban, wilderness) has been extensively studied by researchers in HCI, Human-Robot Interaction (HRI) [43, 83], and CSCW [1, 25, 26, 91]. HRI researchers have studied the use of robots such as drones [21, 29, 42, 81, 102] and land rovers [12, 16, 66, 96] for SAR, and found that control interfaces for such robots should be designed to provide as much spatial and situation awareness of the surrounding environment as possible. Robots have been used in real SAR incidents since at least the 9/11 attacks [16]. Many robots have capabilities that go beyond those of humans and are able to search through areas or from perspectives that humans cannot ever reach by themselves. The obvious example is drones [21, 29, 42, 81, 102], which can inspect large swaths of wilderness environments from overhead perspectives in a relatively inexpensive way (compared to helicopters and airplanes) [21, 42].

Cooper and Goodrich [21] explored the design of interfaces for WSAR field workers to control and view information from a drone. Through their explorations, the authors found that control and information presentation should be simplified, as too much information and control could increase the time and overhead in completing a task. The high-stress nature of the operation can further exacerbate this. Desjardins et al. [26] found the same thing in their explorations of co-located collaboration around beacons during avalanche rescues. Both of these works also found value in presenting information in relation to the layout and physical makeup of the outdoor space. Furthermore, Alharthi et al. [1] found that a sizeable amount of planning and discussion of plans is centred around maps. They recommend mixing individual and team maps, mixing digital and physical maps, and providing the ability to modify and populate maps. I am interested in seeing if such design practices could be extended to remote collaboration activities, such as information sharing between ground search teams and Command.

WSAR planning involves building probability maps based on the characteristics of the lost person using statistics grounded in years-worth of data describing how lost people typically behave in the wilderness [67]. Planning maps indicate the last known position of the subject as well as coloured zones indicating the probability that the subject would be found in that particular area [58, 59, 67, 68]. From these probability maps, SAR managers draw out search paths and define the search techniques that the field teams would carry out [59]. In many cases, the search area grows larger by the minute [58, 59, 67, 68], so WSAR workers must respond quickly and efficiently to increase their chances of finding the subject alive. Search plans are often constructed through proven lost-person behaviour models such as those from Koester [67] and Koopman [68]. There also exist computer programs and mobile apps (e.g., [73]) that help SAR teams build and follow search plans based on proven WSAR models.

This literature tells us about the nature of WSAR. It tells us that managers and planners need to keep track of what has and has not been searched, where everyone is located, how resources are being allocated, and various other things; and use that to plan future actions based on proven WSAR probability models. They need strong team cognition, awareness, and a shared mental model for this. I want to understand how they get the information that they need for these actions while distributed across a large geographic space and transitioning between varying conditions and states of connectivity. Furthermore, there is a gap in our understanding of the nuances of how WSAR remote collaboration around the information collected and the use of probability models takes place, and how it can be better supported with newer technologies.

2.5 SUMMARY AND CONCLUSION

In this chapter, I reviewed the literature on key theories in CSCW on teamwork, including first and foremost the definition of a team, and discussing how both co-located and distributed teams collaborate, share information, remain aware of one another's activities and the task as a whole, and act as a single unified cognitive system through the use of artifacts and different communication styles. While covering this theory, I also related it to the domain of WSAR, by discussing what constitutes a *team* and how teams are structured in WSAR, and reflecting on what we already know about WSAR team structures and workflows. I also covered CSCW research in other emergency response contexts such as disaster response, firefighting, and emergency call centres, discussed the similarities and differences between these settings and WSAR, and highlighted how we could apply what we learned from these works to the context of WSAR. Following this, given that my dissertation work focuses on the remote-collaboration aspect of WSAR, I presented research related to remote-collaboration interfaces, specifically highlighting interfaces that address challenges in video/picture streaming in large environments and while moving around. Given that the design solution I present in Chapter 4 utilizes photo streaming from body cameras to provide contextual awareness to Command, it is particularly relevant to cover these past works. Lastly, in order to provide the reader with a deeper understanding of how WSAR works and what research has already been conducted in the domain, I provided a review of relevant HCI, HRI, and CSCW research in SAR, as well as of relevant theoretical topics such as on WSAR planning.

While we already know a bit about WSAR team structures based on existing training manuals (e.g., [58, 59]) and standard protocols such as ICS [14, 34, 46], and we can also draw parallels to other emergency-response activities, there is still much we can learn through the lens of CSCW theory about the challenges and successes that WSAR workers face in structuring their teamwork, sharing information, and operating as a unified cognitive system when they are collaborating remotely across large geographic spaces (up to several thousand square kilometres) over long periods of time (up to several days). In particular, we have much to learn about how WSAR teams use artifacts, documentation, and communications to support team cognition when working remotely across the field and Command perspectives, and how these processes affect their ability to answer the *who/what/where/when/how* questions of WA and maintain SSA across all three levels (*perception*, *comprehension*, and *projection*). We also have much to learn about how to design new remote-collaboration technologies and information-sharing modalities that support WSAR teams in these actions. In the next chapter (Chapter 3), I present an investigative study that begins to uncover this knowledge. In the subsequent two chapters (Chapters 4 and 5), I introduce an interface design that explores new information-sharing modalities, and present a user study that seeks to understand how it could affect a WSAR response team's ability to attain team cognition and use the process of distributed cognition to achieve WA and SSA.

3

INVESTIGATIVE STUDY

This chapter presents a detailed description of the investigative study I conducted with wilderness search and rescue (WSAR) workers in Canada to understand, through the lens of Computer-Supported Cooperative Work (CSCW) theory, how WSAR workers communicate, collaborate, and share information with each other remotely during a WSAR response. This study was approved by the Conjoint Faculties Research Ethics Board at the University of Calgary and the Office of Research Ethics at Simon Fraser University. This study was conducted in two components: (1) an *interview* component, and (2) an *observation* component. The materials used for this study are in Appendix A.

My findings illustrate that WSAR workers face challenges in maintaining a shared mental model. This is primarily done through distributed communication using two-way radios and cell phones for text and photo messaging; yet both implicit and explicit communication suffer. Workers send messages for various reasons and share different types of information with varying levels of urgency. This warrants the use of multiple communication modalities and information streams. However, bringing in more modalities introduces the risk of information overload, and thus WSAR workers today still primarily communicate remotely via the radio.

This demonstrates opportunities for technology to provide implicit communication and awareness remotely, and to help teams maintain a shared mental model even when synchronous realtime communication is sparse. Furthermore, technology should be designed to bring together multiple streams of information and communication while making sure that they are presented in ways that aid WSAR workers rather than overwhelming them.

This study addresses the first research problem of my dissertation:

- **Research Problem 1:** We have a limited understanding of the challenges that WSAR workers face in remote communication and distributed collaboration.

Through reflection on the study findings, this chapter also begins to address the second research problem of my dissertation:

- **Research Problem 2:** We have a limited understanding of how remote collaboration technologies should be designed to better support building and maintaining a shared mental model in WSAR.

This chapter presents work that has previously appeared in the following publications:

- **Jones, B.**, Tang, A., and Neustaedter, C. (2020). Remote Communication in Wilderness Search and Rescue: Implications for the Design of Emergency Distributed-Collaboration Tools for Network-Sparse Environments. In *Proceedings of the ACM on Human-Computer Interaction, 4 (GROUP)*, ACM.

- **Jones, B.**, Tang, A., Neustaedter, C., Antle, A.N., and McLaren, E.S. (2020). Designing Technology for Shared Communication and Awareness in Wilderness Search and Rescue. In McCrickard, S., Jones, M., and Stelter, T. (Eds.), *HCI Outdoors: Theory, Design, Methods and Applications*, Springer.

3.1 Study Method

3.1.1 *Interviews*

First, I conducted extensive one-on-one interviews with WSAR workers. The purpose was to have participants reflect more broadly on their experiences with WSAR across multiple incidents.

Participants. I interviewed 13 WSAR volunteers (11 men, two women), including four SAR managers and five field team leaders, in order to better understand the challenges from both the field and command-post perspectives. I recruited interview participants from volunteer WSAR agencies in Western Canada through social media, word of mouth, and by contacting individual agencies. The agencies that my participants volunteered for served various communities, small and large, around Western Canada, all near wilderness regions containing mountains, lakes, rivers, and forests. My interview participants were between the ages of 32 and 65 (M = 49, SD = 13), and had between four and 21 years of experience working in WSAR (M = 10, SD = 7). Though I aimed for as much diversity in my participants as possible, the gender imbalance of my participants stems from the fact that, in Canada at least, there are more men serving as WSAR volunteers than women.

Method. The interviews were approximately one-hour long, semi-structured, and took place over the phone, via video calling, or in-person (depending on the availability and location of the participant). I asked participants about their communication practices, their needs, how they use current technology to communicate during WSAR operations, the challenges they face, and how they overcome such challenges. I mainly centred my questions around stories of real scenarios by asking participants to recount past incidents and focus their telling of the incidents on the communication, collaboration, and information-sharing practices and challenges. Sample questions and prompts that I gave participants included *"tell a story about a situation you have experienced in which communication to Command broke down"* and *"tell a story about a situation you have experienced in which it was difficult to make sense of incoming information from field teams."* The full set of questions I asked field workers and field team leaders is in Appendix A.4. The full set of questions I asked Command workers is in Appendix A.5.

3.1.2 *Observation*

To complement my interviews and to see first-hand some of the experiences that WSAR workers shared with me, I observed a simulated WSAR exercise. During this exercise, volunteers from various nearby WSAR agencies searched for fictional lost subjects in a forested and mountainous wilderness area near a medium-sized city in Western Canada. This day-long (eight hour) mock WSAR operation was organized and hosted by a local SAR agency to train volunteers. The event simulated the entire experience of a normal WSAR operation, including a missing person phone call, callouts to the volunteers, setting up a mobile office trailer on site, organizing and sending out search teams, and so on. Only top-level organizers, who were not involved in the simulation as participants, knew all of the details of the simulation, so managers operated without necessarily even understanding where the bounds of the search area were.

Over 100 WSAR volunteers from 14 local SAR agencies nearby searched for 15 fictional lost subjects (who themselves were volunteers from a nearby community) in this exercise. I observed the mock search in its entirety from the operations vehicle at the command post with permission (Figure 5). I acted as a fly-on-the-wall in the operations vehicle, observing and taking notes on the communications coming in from the field teams via

Figure 5: The command post site for the mock-search training activity I observed for the observation component of the investigative study.

the radio, the reactions of the people in the command vehicle to the incoming radio communications, the outgoing communications from Command to the field teams, and the co-located communications happening within the command vehicle (e.g., field teams handing in debrief forms as they return to base, members of the Command team sharing information, etc.). Whenever volunteers were not busy, I asked about the things they did, why they did them, what worked well in their duties, and what challenges they face related to information sharing. I was unable to get a researcher to observe from the field perspective due to safety and liability concerns.

3.1.3 *Data Collection and Analysis*

The interviews were audio recorded and transcribed. For the observation component, I took thorough notes of what happened in the command vehicle, including sketches of inside the command vehicle, notes of what tools and technologies workers were using and how they were using them, and timed logs of key events that happened in the command vehicle such as incoming/outgoing radio messages, when people came in/out, and when people switched roles.

For this study, I was interested in understanding how WSAR workers perform the actions necessary for maintaining distributed cognition today; particularly, how they receive knowledge from individual team members both at Command and in the field, how they store this individual knowledge and turn it into collective knowledge, how they retrieve stored knowledge later, and how they compare, triangulate, and cross-reference the different sources of information they have on hand (e.g., task sheets, radio logs, etc.). Moreover, I was interested in understanding the quality of these interactions, when they succeed, when they fall short, and how these actions differ when working across the Command and field sides compared to between individual members of the Command team. I thus focused my notes from the observation component and my subsequent analysis on moments when members of Command communicated with field teams, when they interacted with artifacts or documentation (e.g., to store, retrieve, or move knowledge), and when these interactions succeeded or failed.

Strong team cognition should of course also be in service of supporting awareness, and thus I was interested in understanding how a WSAR response team's process of distributed cognition (i.e., their creation, transfer, storage, and retrieval of knowledge through communications and artifacts) affects their ability to maintain *workspace awareness* (WA) [44, 45] and *shared situation awareness* (SSA) [32]. Regarding WA, I was interested in understanding how a response team's communication and documentation practices help them remain aware of the *who/what/where/when/how* of a response – *who* is or was in the search area; *where* they are, were, or are going; *what* they did, are doing, or will do; *when* they found certain clues, said certain things, or performed (or will perform) certain actions; and *how* they went about performing certain actions. For SSA, I was interested in understanding how a response team's communication and documentation practices help them *perceive* the current situation, *comprehend* what it means in terms of the statuses of team members and the progress of the response, and use that knowledge to *project* ahead and plan future actions in the response. Thus, during the observation component, I made note of when I observed successes and failures in these. During the interviews, I also asked questions to understand how WSAR workers attempt to maintain WA and SSA, as well as how their collaborative practices and the technologies they use contribute to or hinder their abilities to maintain these. Examples of such questions included *"tell me about an instance in which it was challenging to remain aware of field teams' locations"* and *"how did you try to overcome gaps in your understanding of the present situation?"*

I used open, axial, and selective coding to analyze both the interview and observation data and reveal higher-level themes. Open codes included things like *location awareness*, *sending information*, and *recording information*, while axial codes included categorizations of the open codes such as *awareness* and *information sharing*. My selective codes and themes included *communication goals*, *communication challenges*, and *workarounds to communication challenges*. I did most of the coding, but the codes and what they described shorthand were reviewed collectively and iteratively by two of my supervisors throughout the data-collection and coding phases. I looked at these goals and challenges from the perspectives of both field and Command workers, to understand the similarities, differences, and tensions between their needs and circumstances. To see a complete listing of the codes, please refer to Appendix B.

I now discuss the findings. Interview-participant quotes are listed with *'P#'* indicating which participant gave the quote followed by the main role that she/he indicated taking

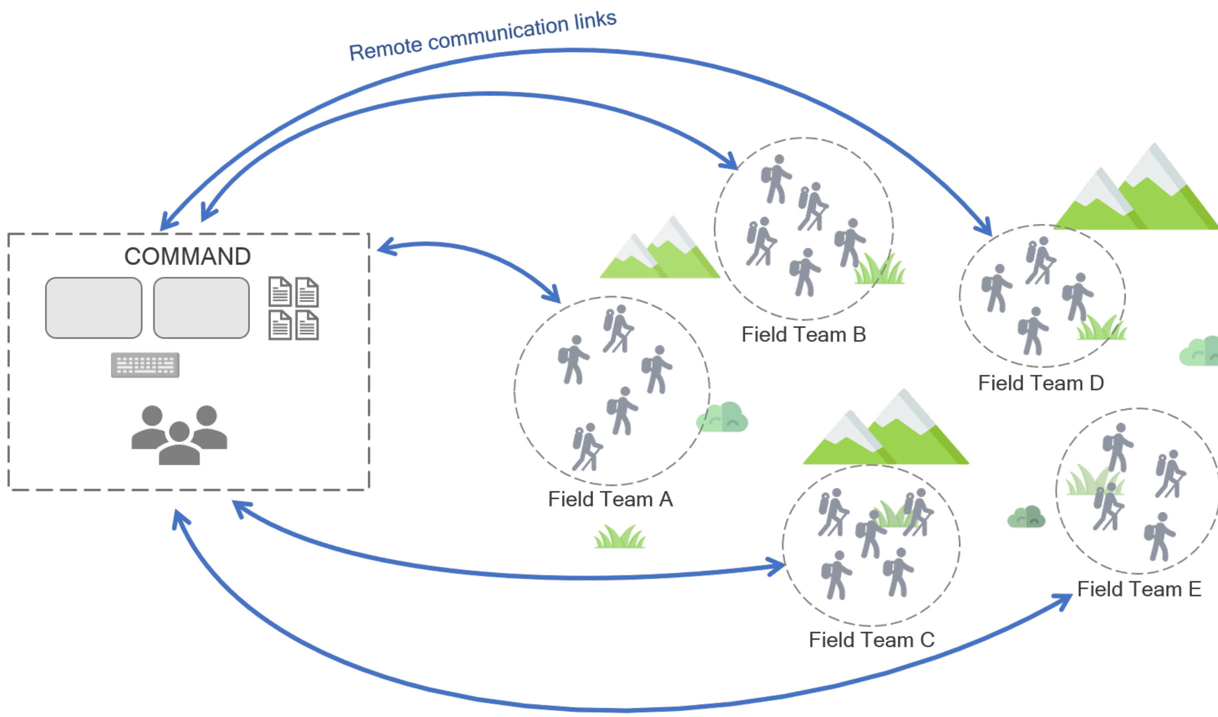

Figure 6: An illustration of WSAR remote collaboration. Numerous field teams (right) search a large wilderness area for the lost person, while the Command team (left) oversees the operation and manages the field teams and resources. All remote communication goes to/from Command, and field teams do not communicate directly with each other. Remote communication takes place mainly using two-way radios (walkie talkies), and sometimes via text and photo messaging with mobile phones.

on (*Field Worker*, *Field Team Leader*, or *SAR Manager*). For quotes from the mock-search activity, I indicate the role played by the person being quoted.

3.2 FINDINGS

Overall, I found that WSAR is a strict command-and-control activity (Figure 6), meaning that information flow is mostly controlled by the Command team, which acts as the 'brains' of the operation. Most information and communications flow either to or from

Command, and Command is vested in maintaining shared agreement, consistency, and control across the response team as a whole, maintaining awareness of all key events that take place in the field, and making sure all workers are safe. Meanwhile, field teams are heavily focused on finding the lost person, based on Command's directions, and feeding new information to Command so that they can help the response team as a whole narrow in closer to finding the lose person. In the following sections, I highlight in detail the specific collaborative practices the two sides engage in while striving for these goals, and the challenges they face in doing so, particularly when they are working remotely.

As I present the study findings, I highlight and list six major *insights* (*I*s) that arise from these as *I*# (e.g., *I1*, *I2*, etc.).

Figure 7: The inside of the command vehicle, where the Command team oversees the operation and coordinates field teams. The command post is filled with written forms and physical artifacts placed over walls, desks, and whiteboards.

3.2.1 *Documentation, Logging, and Awareness*

At Command. SAR managers rely heavily on written forms, physical artifacts, and their positions in the command office (Figure 7) in maintaining an operational picture and shared mental model. This information is useful for planning, record keeping, and maintaining situation awareness of the statuses of teams and resources, especially when unable to directly observe them. Through these forms, command workers can still be aware of what everyone is supposed to be doing and make predictions (based on how much time has passed) of how much progress each team has made in their assignments. In direct accordance with distributed cognition, knowledge is contained in the artifacts spread out across the command vehicle.

When the first SAR managers arrive at the scene and after they have set up the staging area with the command vehicle(s), they begin filling out forms. I observed that these forms include (but are not limited to): a subject description, Incident-Command-System (ICS) forms indicating the roles and tasks to be assigned, and maps of the search area including probabilities and search paths. As volunteers arrive at the staging area, they report to the manager on duty and sign in. Once the Command team finishes creating a response plan, they call all the volunteers on site and do an initial briefing (Figure 8).

During the simulated response I observed, the Command team first gave the volunteers a task number, followed by describing the scenario. In this training scenario, it was a helicopter crash in the forest, and there were 15 crew members on board who were now missing. They gave the time of the crash, descriptions of the subjects and the aircraft, the estimated location of the crash based on eyewitness reports of where the helicopter was flying before it crashed, and the types of clues that the volunteers should be on the lookout for. Volunteers were given a short description of the search area, including

Figure 8: Field workers gathered for an initial briefing before being deployed to the field.

what features (hills, streams, boulders, etc.) were contained within it. They were also told safety information such as the weather forecast, the recommended clothing, and amount of water needed. While all of this information was being relayed, I observed volunteers taking notes in pocket notebooks which they then carried with them into the field.

Volunteers were then organized into teams, and each team was assigned one experienced SAR worker to be the team leader. The teams were then given their task assignments. For each team, a manager briefed the team leader, who would then brief the rest of the team. Command gave each team a set of paper maps and forms with the subject description, and notes on the type of search to conduct, which locations to search, and what to be on the lookout for. Field teams were to rely on this information when out in the field performing their duties. Both Command and the field team had a copy of the same task and role assignment forms. Photocopies were made immediately after the forms were filled, so that Command could keep a copy to place on the wall. This allowed them to keep track of who was deployed in the field and what they were doing. Command's

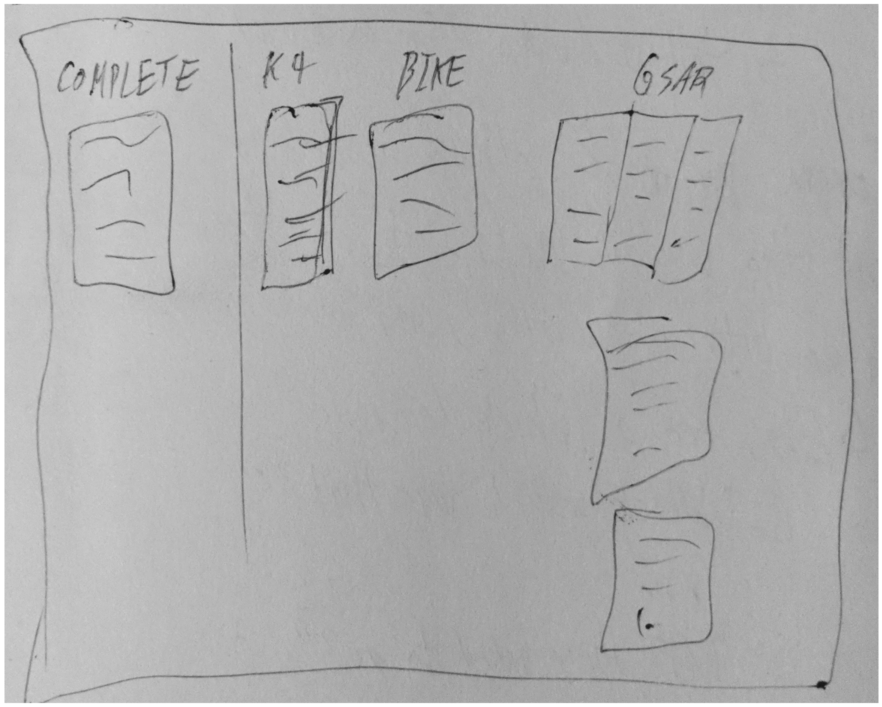

Figure 9: An sketch of how the Command team arranged their own photocopies of teams' assignment sheets on the wall, to keep track of who is deployed, what they are doing, and who has completed their assignments. I drew this sketch in the command vehicle during the mock-search observation. Given that the actual forms contained confidential information, I could not take a photo of their arrangement.

photocopies of these forms were arranged on the wall in a manner that helped them keep track of these things (e.g., Figure 9). Each field team carried at least one GPS-equipped radio transceiver with them for communicating with Command. When teams returned, they would do a post-assignment debrief, their forms would be returned to management, and management's copies of the forms would be moved to a section of the wall showing the completed assignments.

> *"We use whiteboards and erasable pens. We also use the physical team assignments, so we'll write the team assignment, what they're doing, where they're going, and then once they check in that they're in the field, then we move [the form] to a different location [on the wall], so now we know they're in the field." – P4 (SAR Manager)*

From	**To**	**Time**	**Summary**
Team A	Command	2018-07-14 13:06	Reported finding a brown jacket. Location: *XXXX*
Command	All teams	2018-07-14 13:08	Informed teams that subject removed his jacket, be on the lookout for someone without a jacket and wearing a red hat. Last known location: *XXXX*
Team B	Command	2018-07-14 13:09	Team did not hear Command clearly, asked if subject removed his red hat
Command	Team B	2018-07-14 13:10	Clarified to Team B that subject took off jacket, is still wearing red hat
Team C	Command	2018-07-14 13:27	Reported that their dog is injured, requesting medical assistance. Location: *YYYY*
Command	Team C	2018-07-14 13:29	Informing Team C that Command is sending a team with medical resources to their location: *YYYY*

Table 1: An example of a radio communications log manually recorded by the communications officer at Command.

> *"The team leader will take a photocopy of that task sheet with him/her out into the field and the original will stay at Command. When the team comes back in, the team leader will [...] do a written record of what they did, what they encountered, what they found, all that stuff. And then [the] team leader will sit down with someone from Command and go over it." – P6 (Field Worker)*

I observed that the Command team carefully logged all radio communications. During the search phase, all radio communications between the field teams and Command took place on a single radio frequency. The SAR manager assigned one person to be the *communications officer*. This person was in charge of talking to teams in the field on the radio on behalf of Command, and logging all of the radio communications that take place. I observed that this logging is precise, complete, and extensive, with the goal for there to be as much accuracy as possible. The communications officer did not necessarily log each message word-by-word, but rather logged each higher-level 'communication event' in a row on a spreadsheet (e.g., Table 1) with the following four columns: (1) who the message was from; (2) who the message was to; (3) the time of the message; and (4) a higher-level summary of the message, event, or reason for the communication. There were two reasons Command was logging this information: (1) to keep a time log of key events to possibly refer to later, and (2) to protect themselves for liability purposes.

> *"If we're walking along the road and I find a gold bracelet with a cross on it on the side of the road, I'll radio Command [...] They'll log that. [...] Then let's say the next day the family members come up and say 'oh we forget to tell you that little Susie has a gold bracelet with a cross on it.' We can go back and look at that record and say 'oh we found this bracelet at this location at this time.'" – P11 (Field Worker)*

This allows the knowledge to be stored in an artifact after transmission from the field to Command, and used at a later time, possibly by other workers. In accordance to distributed cognition, this piece of knowledge is thus contained in the workspace and belongs to the responding organization, rather than just a few individuals within it.

In the Field. Field teams also relied on documentation (consisting of both forms they and management filled out, as well as hand-written notes) to recall what they were supposed to do and where they were supposed to go. However, in contrast to the Command team, who had an awareness of the bigger picture, field teams had a more-focused lower-level picture of things, in relation to their current task assignments. According to some SAR workers, this level of detail was usually enough to complete their duties.

> *"[Field teams] know who they're looking for and the generals, but they don't need to know what the big picture of the search is. They're going to go to the area that they're told to, [but] they may not even know why." – P4 (SAR Manager)*

The best case meant that conditions in the field were as Command expected them to be, and the field team did not run into any unusual or unanticipated challenges. However, this was not always the case. Sometimes a field team would run into an obstacle that prevented them from conducting their search assignment exactly as they were requested to. For example, in the simulated search I observed, a team radioed Command to inform them that they were observing more trails around them than were shown on the map that they were given. Later in the operation during the rescue stage, another team that was searching for more subjects on their way to the crash site encountered boulders along the route they were supposed to take, and they could not pass through. Thus, they had to take an alternate route. They informed Command on the radio and also shared the location of the boulders, so that Command could keep track and perhaps inform other teams in the area.

> **[I1]** *WSAR teams want to maintain a shared mental model, and they use artifacts, documentation, record keeping, and communications in support of this.*

3.2.2 *Consistency, Agreement, and Control*

My analysis showed that WSAR workers used documentation and communications to maintain a shared mental model on key aspects of the operation (e.g., shared agreement and common ground on what was to be done). Command did not want there to be discrepancies in what a team was doing and what Command expected them to be doing. They wanted consistency, clarity, control, agreement, and shared understanding. When a team did something that was unexpected, Command needed to know why. A single team deviating could have affected the entire operation, and Command would have needed to adjust their operation plan around changing conditions in the field or a team deviating.

"As a non-military organization, we sometimes face the issue of giving a field team leader a task, only to realize they decided to do something they thought was more 'important'." – P13 (SAR Manager)

There are sometimes valid reasons for field teams to occasionally deviate from their assignments, and Command often knows this. During an operation, Command does not experience the conditions of the field first-hand, so they are not always able to judge for themselves whether or not a course of action can be taken. They generally trust the team leader to make that call:

"[We're] content to just let them do their job. [...] We don't need to micromanage. We can trust the team leader to make sure that things are being done correctly. But having said that, we still need constant radio communications or equivalent because of changing information." – P10 (SAR Manager)

"All kinds of things can happen. Maybe [there are] some natural features there, it all looks great and flat and clear on a map in the command post where I'm warm and dry, but out in the field, the reality [could be different]." – P4 (SAR Manager)

Nevertheless, Command still needed field teams to inform them of when they deviated, and for what reason. When they did this though, this communication was not always clear, especially over the radio:

"The helicopter pilot dropped me in the wrong place [...] and I let command know, [but] they didn't quite understand. When I got back with my team, it's like 'Where did you go?' 'Well, here.' 'Why did you go there?' I'm like 'Because the helicopter couldn't land there, so we searched the area we were in.'" – P4 (SAR Manager; describing an incident when he played the role of Field Team Leader)

In order to make sure that teams were on track, Command generally wanted to maintain consistent radio communications with teams when they were in the field. I observed that teams contacted Command to give routine status updates at least once every hour, and sometimes more frequently if they encountered things that they feel are important to share with Command. Command wanted to ensure that the teams were safe, that they were performing their assigned duties properly, and they wanted to understand what challenges teams faced. Command wanted new information to keep flowing in so that their mental model kept updating. This also kept the teams in touch with Command, in case Command needed to send them new information.

> *"We always want to know where our teams are in the field and how they're doing." – P10 (SAR Manager)*

> *"You're listening to the radio all the time, so you're getting an idea of what teams are encountering, what they're doing." – P4 (SAR Manager)*

> *"For me as a team leader, I'm updating command with what our next move is, if we found the subject, or noticed any along the trail that could impede the other teams. But [we] don't [...] make a big deal out of it. It literally is just to see that you're alive and that everybody is doing [well]." – P5 (Field Team Leader)*

In WSAR responses, there are also times when SAR managers need to inform teams of updated information that is relevant to their tasks. For example, during the mock search, once the crash site location was found by one of the field teams, Command informed all of the other teams via the radio that the site had been found. Command then communicated the location of the site to the teams (as a set of UTM location coordinates). Afterward, Command radioed some of the teams individually (by calling their team number; e.g., *"Team 102, come in."*) and asked them to make their way to the crash site location while being on the lookout for victims along the way. Another example from one of my interview participants:

> *"At some point, [...] we need everybody to know about [new information]. [...] 'Okay, now they're barefoot.' That's important to know if people are looking for tracks, [...] that would be the kind of collective knowledge that would need to be spread out." – P4 (SAR Manager)*

During the mock search, I observed that the communications officer and others around her in the command vehicle would occasionally watch out the windows in front of them to see bits of what is happening outside of the command trailers. This view allowed them to see teams leaving to and returning from their assignments. At one point in time, the personnel at Command watched as a vehicle left on its own:

```
[Vehicle starts to leave the staging area.]
Operations Manager: Which vehicle was that? [...] Were they asked to go?
[Vehicle goes out to the field on their own, without instruction from Command.]
Operations Manager: Unacceptable!
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As soon as a team or volunteer self deploys, their mental model of what they are doing becomes inconsistent with that of Command. This leaves Command with an incomplete understanding of the operation and the people/resources available, hindering their ability to make proper decisions and keep everyone safe.

> *"If we're not asked to [go] in, then it's not our job to go in. We don't self-deploy. That's management. They have the big picture. We have our focus picture." – P1 (Field Team Leader)*

This even goes so far that Command gets upset when field teams do not properly check in or out when they are supposed to. In the mock search, I observed Command personnel scolding field teams who returned without informing Command of their return, even if workers at Command were able to observe them returning through the windows of the command vehicle. This illustrates that Command workers were quite serious about maintaining control and consistent agreement about the situation (i.e., a shared mental model) between them and the field teams – so much so that they reacted harshly to any perceived deviances from the agreed-on tasks and procedures by the field teams, at least when Command was not informed of such deviances.

> **[I2]** *Maintaining a shared mental model is difficult across field and Command perspectives.*

3.2.3 *Reception Gaps*

Remote communication between Command and field teams primarily happened via the radio. I observed that it is the primary way that Command kept in touch with the teams and updated their mental model of the operation, as they were unable to directly observe or communicate with teams face-to-face when deployed. The challenge, however, was that radio reception was often unreliable in the wilderness. Reception gaps in the wilderness contributed to an asymmetry of workers' knowledge of details of the operation, and a breakdown in the shared mental model. As a result of these radio gaps, field teams constantly moved in and out of radio coverage, leading to Command not always having constant communication with the teams. Further, field teams sometimes did not know if they were out of radio range, or even what information they are missing if they were out of range.

[The radio] usually doesn't work well. [...] I can't actually think of a situation where I've been happy with [communications] ever." – P3 (Field Team Leader)

"Very often radio communications [are] quite sketchy. [...] We'll be in areas where we just can't communicate with Command and they can't communicate with us. We have to keep going until we get to a point where we can communicate. That happens all the time out here." – P11 (Field Worker)

I found that unreliable communication with the teams could increase the time it takes for new information to flow in, leading to Command's mental model of the operation being incomplete. If command did not have the most up-to-date information, they were not always able to make the best decisions given the present situation. Command workers are concerned with receiving as much information from the field as possible in as short of a time as possible and keeping in touch with the field teams to know where they are, how they are, and what they are doing.

"What [you're doing as a] SAR manager is [...] trying to make sure that all your teams are proceeding as directed and that everyone's safe. It's nice to know that at all times. When you don't have communication, you make that assumption, but until you've got communication again you don't know that. It's hard when you have dead spots when you can't get in touch with people." – P8 (SAR Manager)

When Command does not have consistent communications with field teams, they can only make assumptions and predictions of their statuses and progress, based on their last-known status. They can only make an inference or prediction on where they might be, based on their last status update, their given task assignment, known conditions in the field, and any other knowledge they might have in the current moment.

Additionally, information from Command may not always get passed on to all of the necessary teams in the field right away, if there are some teams out of radio range. If a team does not answer the radio right away, Command cannot wait for them to become available, as management must attend to their own duties and respond to incoming communications from other teams.

> *"We were searching for maybe 40 minutes longer than we had to be, because we were in a radio dead zone. We didn't get the update that the person had been found." – P7 (Field Worker)*

Radio gaps also resulted in field teams hearing only parts of a message or conversation. Additionally, they did not always hear messages from everyone if they were in an area where they were within radio range of some teams but not of others.

> *"If we're all on the same channel, you could hear the conversations on that. [...] You don't [always] hear both ends. But if you've got teams that are in your area, [...] you'll hear what they're chatting about. Like [for example] the other day, when the [subject] was located, that team [that located her] was close to us. And so immediately we heard [the team say on the radio]: 'subject responded'." – P1 (Field Team Leader)*

Hearing gaps in radio messages made it difficult to put the radio conversations into context when a field team only heard some of it.

[I3] *Radio/cellular reception is sparse and not always reliable.*

3.2.4 *Communication Prioritization and Discretion*

The fact that all radio transmissions were sent and played in the same way meant that all information, whether it was crucial or mundane, was being heard on the other side in the same way. This introduced the potential for the recipient to misunderstand the true priority level or urgency of some message. Not all information may need to be communicated or received in the same way, and indeed sometimes field teams used other communication modalities, both synchronous and asynchronous, to get their message across. These ranged from SMS, picture messaging, and location data. If the information was not urgent, sometimes teams even waited until they returned to Command before sharing it, or they sent it as a message without needing an immediate reply.

As an example, it can be challenging for a field team to get Command to understand the importance of some piece of evidence from the field over the radio:

> *"Often [...] you'll have something that maybe you think is of particular relevance and Command does not seem to be taking it as seriously as you think they should. Very often Command will just tell you to stand by and you don't hear anything." – P6 (Field Worker)*

Workers tried to add priority to radio messages using standard terminology:

> *"We can get priority for a radio transmission via the use of either, depending on severity, 'no duff' or the next step up 'pan pan pan' or the max urgency 'mayday mayday mayday'." – P2 (Field Worker)*

Even when something was important to share with Command, a team may have sometimes needed to wait to send it, as Command might have been too busy to answer in the moment. This could have been due to there being multiple people coming in and out of the command vehicle to exchange information, or multiple field teams wanting to send information to command via the radio at the same time.

> *"Sometimes you might have a situation where there's 10 or 12 teams out on the field, all wanting to communicate with command at the same time." – P6 (Field Worker)*

During the mock search I observed, once the crash site had been located, the radio channel became so overloaded with communications from the field teams that the radio operator could not handle all of the messages by herself. At this point, another member of the Command team took on the role of a second radio operator and opened up another radio channel; thus leaving one channel open for teams still searching for subjects, and another open for teams who were extracting subjects that were already found.

To avoid waiting on the radio, interview participants have said that some agencies allow members to send text messages for less urgent messages or messages that do not need to be read immediately. Some workers coupled these with photos if they needed to show something.

> *"Cell phones may work, if not then [satellite] phones [or the] text-message capabilities of new [satellite-phone] devices." – P2 (Field Worker)*

In other cases, participants said that teams sometimes wait until they return to Command before giving them some of the information they have collected, to avoid cluttering the radio with chatter. For example, I observed that when a team returns to command, the team leader would give the team's GPS-equipped radio to a manager, who would then upload the GPS record to a computer that would then display the path the team took overlaid on a map of the search area. Over time, this digital map would populate with the paths taken by teams and pins showing key locations, such as where clues were found, thus constructing an information picture of the status and progress of the search.

> *"Teams come back with their GPS. It's uploaded, and you gradually build a map of what teams have been where, and you have your different colours. So the dog team's been through here, we got a hasty team through there, [...]" – P4 (SAR Manager)*

This gave teams an opportunity to explain the route they took, the actions they performed, and the things they found while conducting the in-person debrief with a SAR manager. This was easier to do at Command than while the team was in the field and in the midst of their task assignment. The lack of clarity of some messages over the radio, the difficulty of using the radio while trudging through the wilderness, and radio reception gaps made it more feasible to share this larger amount of information at Command, after it had already been logged automatically by a device.

> *"If it's not super urgent [...] it just kind of clutters up the radio chatter trying to tell them where we are. So, we just mark [where the clue is] on our GPS, so when we go back to Command, they can download it." – P3 (Field Team Leader)*

The decision of whether or not to pass some piece of information on to Command was usually left to the discretion of the field team, and most often the team leader. This left open the potential for Command to miss some crucial information they needed, simply because the team did not think it was important to send that information.

In particular, if a team has a less experienced team leader, or even one that does not share the same perspective or knowledge of Command, they might not know what information is important to pass on:

"People are human and sometimes maybe it's a team [without] a particularly assertive team leader and they may be like, 'we kind of found this thing but we don't really think it's important,' so they don't push it." – P4 (SAR Manager)

Lastly, in order for a team to talk to Command on the radio, they must stop what they are doing and find a location where they can get radio connectivity with Command. This often distracts them from their focus on their assigned duties and uses up time that could be better spent searching for the subject.

"If you are going and stopping and trying, it takes away [...] There's decreasing returns if you put a whole lot of effort into finding a place where you can get a hold of base and tell them, 'nothing to report'" – P2 (Field Worker)

For this same reason, SAR managers were also hesitant to page field teams for status updates when they were silent on the radio for a while.

"Every time you radio [a field team] ... they're skiing along, they have to stop, they have to take their gloves off, depress the radio [button] ... it slows them down. It's a hindrance to them." – P8 (SAR Manager)

Some newer radios come equipped with GPS transceivers, which allow command to obtain the location of any field team within radio reach in realtime through the click of a button. This was the case for the mock search I observed. SAR managers have expressed that obtaining information in this way is helpful, given that it comes immediately and updates as frequently as they want it to, and they have also said that it is comforting to know that they can get this information without bothering the field teams.

[I4] *Workers want to prioritize communications.*

3.2.5 *Awareness, Distraction, and Level of Detail in the Field*

Field workers sometimes want to maintain a shared mental model that is consistent with Command's mental model and higher-level awareness. In particular, field-worker participants have said that they want workspace awareness of the environment and other field teams' activities, and higher-level situation awareness of the bigger picture of the search status, to the extent that it is relevant to them. They want to know how the bigger-picture of the search is evolving, and they want to know how their actions are contributing to the search response as a whole, so they can understand their impact on the operation and feel less isolated from their team mates. While this is the case, I was told by SAR managers that field workers are supposed to be focused on the in-the-moment demands of the wilderness environment and the search task they were given. This presents an important tension. A team's focus on their assigned duties is beneficial to the operation as a whole (and thus the safety and livelihood of the subject), as it increases the likelihood that they find the subject sooner. On the other hand, remaining aware of one's role within the bigger picture and in relation with everyone else could boost a team's morale, as it could serve as a reminder that the team's focused actions are meaningful to the operation as a whole. A field worker's ability to hear other remote teams may help boost this morale, similar to how players of online video games feel a higher sense of team commitment when they are able to hear and communicate with their team members [24]. Especially in large and difficult searches, WSAR workers often want to know if they are making progress and what is going on elsewhere. This is why they are interested in the radio chatter. But too much of this can become a distraction. In some cases, field teams have even shut off the radio because they were hearing too much radio chatter, and it was hindering their focus.

"It depends on the task but sometimes [hearing radio traffic] is obnoxious, where you have to turn the radio down and hopefully remember to turn it back up again." – P3 (Field Team Leader)

While this is the case, there is also an inherent curiosity about what others are doing, and whether they have found clues:

"I know that I'm always listening; like if I'm not busy, say we're just walking down a trail and looking for clues, I'm always interested in what other people are talking about." – P3 (Field Team Leader)

This curiosity is part nosiness, but also a desire to understand the bigger scope of the search. This could be beneficial in that it could reduce a field team's sense of isolation, boost their morale, and encourage a greater sense of belonging with the entire responding organization (i.e., all personnel who are part of the response). This idea of trying to foster a 'large team' approach is also something that resonated with SAR managers.

"I felt that I was always working hard to sort of foster an atmosphere of inclusivity and sharing information. So I'm naturally in favour of as many people knowing the bigger picture as possible." – P10 (SAR Manager)

Participants said that this awareness could also have a potential utilitarian purpose. For example, it could allow field teams to know if other teams have found or passed along information that is relevant to them and their duties and allow them to coordinate with other nearby teams if deemed necessary. However, not all SAR managers agreed with this:

"[The] right [approach] isn't necessarily to give the field teams more information about where they are in the context of other efforts, but the right level of detail." – P13 (SAR Manager)

Workers understand this fundamental tension, as the field workers' tasks alternate between moments of boredom (walking through the forest) and times when extreme focus is required (e.g., navigating a gully). Essentially, increased awareness of other field teams could be useful when their work becomes more tightly coupled, when they need to collaborate on something, but less useful when their work is loosely coupled (which is most of the time), when they are focused on their task assignment, even if the increased awareness leads to a boost in morale.

> **[I5]** *Field workers want greater awareness beyond just their team, but they also need to remain focused on their activities.*

3.2.6 *Inter-Team Communication*

While field teams can generally overhear a lot of communication between Command and other teams, protocol prohibits a field team from communicating directly with another field team without going through Command first, even though field teams can generally hear each other on the radio. This is unless they have explicit permission from Command to communicate directly. Participants said that there are two reasons for this: (1) Command wants to have control and awareness of all information passing through the radio channel, and (2) Command wants to prevent the radio channel from having too much traffic.

> *"[Command doesn't] want to miss anything, and if one team was talking to another team [...] maybe that could happen." – P6 (Field Worker)*

SAR managers also said that permission to communicate directly with another field team is usually granted for one of two reasons: (1) the team needs to directly coordinate resources or actions with another nearby team, or (2) the team needs to act as a radio relay to Command for another field team that is out of radio range of Command but within radio range of the first team.

> *"[A field team] can ask Command for permission to talk directly to another team, and that would be because they need to share information, but Command is still monitoring and still aware of that information." – P4 (SAR Manager)*

During the simulated operation, I observed one instance of a team requesting permission to talk directly with another team. In this case, it was during the rescue stage of the operation, and one of the teams needed to split into two smaller teams to extract subjects in separate nearby spots. Given that they were deployed with equipment for one team, they needed to coordinate their shared resources via the radio.

One reason that it was beneficial for two field teams to communicate directly with each other in these types of situations is to avoid any loss of information from having messages go through Command first.

> *"If you're running into obstacles out in the field that are hard to get past. [...] it's often useful to communicate directly rather than have a go-between that could distort the message." – P6 (Field Worker)*

The more direct communication is, the more efficient and clear it is. This is especially important when teams are coordinating with each other or passing along lower-level details. Teams have done this when, for example, they needed to inform a nearby team of hazards, or share navigational instructions. In these cases, it was especially helpful to have local knowledge and guidance from someone who was actually 'out there'.

3.2.7 *Use of Other Remote Communication Modalities*

My analysis revealed that Command needs to fully understand the information that field workers pass to them in order to make good decisions based on it. They also need to understand this information as quickly as possible. When every second counts, delays and misunderstandings can lead to a reduced likelihood that the subject is found alive. There is a potential for other communication modalities and information streams such as pictures and videos to support quicker understanding of information. However, some SAR managers are concerned that bringing in more modalities could introduce the risk of information overload, and it could become too much information for Command to manage and control.

There is opportunity to present information that is rich in visual detail through means such as photos and videos. Just like in firefighting [38], it can be easy to make mistakes in listening and communicating over the radio in WSAR, and these mistakes can have serious consequences. In particular, WSAR workers can easily miss key details or take a long time to describe or understand information that is rich in detail. This becomes more likely given the stressful demands of their work. For example, if a field worker is facing a lot of stress due to environmental demands or the demands of their assigned task, they may not be able to describe some important piece of information in a coherent way. Similarly, if the radio operator at Command is unable to listen to details through the radio as easily due to distractions in the command post, they may easily miss a crucial detail given by a field team.

Examples of information rich in details that can be hard to describe or understand via the radio include the visual properties of clues (e.g., footprints, objects), the geographical layout of a spot (e.g., where trees, rocks, hills, and bodies of water are found), and first-aid information (e.g., the medical state of the subject). Sending images or videos of this type of information could be beneficial.

> *"I could imagine using [pictures or videos] in situations where, if you're in the bush and you're looking for an example helicopter landing zone, if you're looking for a route out, or [...] you can send pictures of the condition people are in." – P9 (Field Worker)*

In recent years, some field workers have begun to send images of clues to SAR managers via SMS/MMS messaging.

> *"We'll obviously be taking pictures with our phones and in the last five or six years we, text messaging is so good I'll just text my SAR manager a picture and he'll be like, 'Yep, that's their footprint' or 'Nope, that's not their foot.'" – P3 (Field Team Leader)*

While pictures and videos could aid field workers in describing the conditions of a scene to Command or help them convey a message, verbal descriptions are still useful in some circumstances; either on their own or coupled with images or videos.

> *"Terrain's usually better described by whoever's out there. It's hard to look at a picture and know what the real situation is." – P8 (SAR Manager)*

While some SAR managers and agencies embrace newer communication channels, they can still lead to potential challenges. For one, adding more channels could make it increasingly challenging to maintain a mental model of the operation, as the workers at Command may have to pay attention to multiple information streams.

> *"I know from being a manager I receive information via voice, text, email and radio already, and synthesizing an operating picture out of those different streams can be very challenging. There are many things competing for my attention during a search." – P13 (SAR Manager)*

In addition to this, adding more styles of communication affects work protocols, requires training in their use, and potentially introduces more points of failure in the operation.

> *"The strength of the current system is that it is durable and fault tolerant, where most digital systems introduce more single points of failure and fragility. A functioning radio, a white board, some pens, and some paper is the basics of a SAR management system. Adding more tools and technology introduces opportunity for failure in the devices, protocols and training of the individuals." – P13 (SAR Manager)*

There are two things that this suggests: (1) aggregating existing information streams before introducing new ones might be more beneficial, and (2) careful consideration should be taken before introducing a new information stream, to determine whether or not it is actually necessary or helpful to the operation.

> **[I6]** *Other communication modalities could provide different levels of understanding, but care should be given not to overwhelm the worker.*

3.3 DESIGN OPPORTUNITIES AND RECOMMENDATIONS

The findings from this study demonstrate that while maintaining a shared mental model is important for a WSAR response, there are many aspects of WSAR that make this challenging. In this section, I highlight three *design opportunities* (*DO*s) for new technologies to address remote-collaboration challenges in WSAR.

[DO1] *Technology can be designed to help bridge the perspectives of the field teams and Command through implicit and automatic information sharing.* (I1, I2, I5)

There are opportunities for technology to support implicit communication, information sharing, and awareness remotely in addition to explicit communications such as radio updates and text messages. Implicit communication and awareness are almost non-existent across the response team as a whole, particularly between the field and Command. Even though members of the Command team are aware of their colleagues actions in the command vehicle, and members of individual field teams are aware of their co-located partners' actions, there is little implicit communication and awareness of others' actions beyond just these smaller sub-teams. Technology design should explore adding additional implicit communication and information-sharing channels to WSAR remote communications, in order to enhance awareness across the response team as a whole.

Given the command-and-control structure of WSAR, much of the focus (at least initially) should be on bridging the perspectives of the field and Command. Implicit communication/information channels from the field to Command already exist to some extent, as Command can observe the GPS locations of field teams, look at forms and documentation, and eavesdrop on radio conversations. Though even with all of this, Command still needs to put a lot of effort into communicating explicitly with the field teams to get an updated picture of their statuses. Much of this information still does not come automatically or implicitly. Gaps in radio coverage worsen this problem. By allowing for more status information from field teams to come in automatically, this could save time on Command's part and allow them to put more attention toward other activities. As a simple example, it could be worth it to explore body cameras worn by field workers that automatically take and send geotagged photos of their surroundings to Command, where they are then displayed within digital maps of the search terrain. Photos could be shared either periodically (e.g., every ten minutes) or during key events such as when they have reached a certain location or when they are stopped for a long time. Software could allow WSAR managers to 'scroll through' time and see how the content and location of the photos change over time.

[DO2] *WSAR workers could benefit from additional remote-communication modalities and information channels beyond just audio and text.* (I4, I6)

Based on the study findings, WSAR workers, teams, and agencies could likely benefit from having multiple modalities of communication and information sharing at their disposal, each useful for certain situations For example, photos may be useful for describing clues, maps may be useful for describing locations, and text may be useful for quick status updates. Currently, however, a lot of the remote communication in WSAR happens via the radio, which does not do well at presenting different types of information in useful ways, at useful times, or giving it the necessary prioritization. Research should explore adding new communication modalities to WSAR.

[DO3] *WSAR workers could benefit from additional opportunities for asynchronous communication and information sharing.* (I3, I4)

The study findings indicate that, as a result of radio reception gaps, information can propagate slowly. A lot of the information exchange between field teams and Command happens before and after task assignments, due to both the unreliable reception in the field and the fact that field teams are heavily focused on their tasks while in the field. While it has its downsides, lack of realtime communications can also sometimes be beneficial for field teams, as it allows them to focus on the task of searching and collecting information. Thus, there is potential opportunity for asynchronous communication and information sharing that should not be ignored in explorations of WSAR remote collaboration.

As an example, a field team may want to share some piece of information with Command, but they do not need them to view or respond to it immediately. A team outside of radio coverage could queue up a message to Command that would send as soon as they regain contact with Command. Additionally, a team would not have to wait for Command to become available before sending a message to them. A team could send a less-urgent message to Command quickly, then carry on with their duties. WSAR workers have cited this as a reason for sending and receiving text messages and photos.

I also outline the following three *design recommendations* (*DR*s) to follow when pursuing these opportunities:

[DR1] *Anticipate network sparseness, and design communication modalities and information channels that take these into account.* (I3)

While there are some technological solutions, like radio repeaters and mesh-networking technologies (e.g., [112]) that could help minimize disconnectedness between field teams and Command, more could still be done to provide WSAR workers with relevant information and awareness while disconnected. For example, it may be worthwhile to explore technologies that present workers with relevant 'offline' information; i.e., information that is already there, and can be presented to the user at the relevant time while 'offline'. For example, it could be beneficial to show a field team how much of their assigned area they have covered, or show Command a prediction (through probability models or artificial intelligence) of where out-of-contact teams may be located and how much progress they are likely to have made at the current time, based on their given assignments and other factors such as weather. While the information may not be perfectly accurate (e.g., it may be out of date or 'stale'), it could still provide Command with more to work with than just receiving nothing. As a similar example on the field side, when field workers are 'offline', technology could give them relevant information such as expected weather changes that are imminent, where other field teams are predicted to be, and predictions of when Command might want an update from them.

[DR2] *New technologies should not burden or distract workers.* (I5, I6)

This is true for both field workers and Command. For Command, technology should provide minimal distractions from planning and operations duties. For field workers, technology should provide minimal distractions from immediate surroundings, allow them to communicate hands-free if possible, reduce the time needed to send and receive messages, allow them to respond to less-crucial messages when they are less busy, and allow them to focus on listening and being on the lookout for the lost person.

[DR3] *Communication modalities and information channels should be aggregated, to allow for easy viewing, searching, sorting, and comparisons.* (I6)

One of the biggest challenges I found is that there is a lot of information coming in from the field, and SAR managers have to bring all of this together and make sense of it. While there could be a potential benefit to introducing other channels such as video, bringing in more information streams introduces a greater risk of mental overload. Thus, the information should be carefully managed, aggregated, and presented such as to not overwhelm the intended user. Based on the study findings, I recommend presenting information in different ways (e.g., as a location on a map or an event on a timeline) and with different levels of detail, depending on who is viewing it and in what context they are viewing it. For example, if a manager pulls up a task assignment number, they may be interested in looking at the rough search path and the area covered. If a field worker pulls up the same assignment number, they may be interested in seeing lower-level details on the search techniques to carry out, the landmarks in the field to watch out for, and the equipment they need to bring with them. Moreover, a field worker may be interested in seeing the search path in relation to their own first-person view of the environment, whereas Command may be interested in seeing it overlaid on a map.

3.4 SUMMARY

In this chapter, I presented an investigative study into the work practices of WSAR, which provided insights into how commanders and field teams communicate, collaborate, and share information when scattered across distances and throughout the duration of a response. From these, I presented design opportunities and recommendations for technologies to address the remote-collaboration challenges faced by WSAR teams.

To summarize, these were the main insights from the study:

- **[I1]** WSAR teams want to maintain a shared mental model, and they use artifacts, documentation, record keeping, and communications in support of this.
- **[I2]** Maintaining a shared mental model is difficult across field and Command perspectives.

- **[I3]** Radio/cellular reception is sparse and not always reliable.
- **[I4]** Workers want to prioritize communications.
- **[I5]** Field workers want greater awareness beyond just their team, but they also need to remain focused on their activities.
- **[I6]** Other communication modalities could provide different levels of understanding, but care should be given not to overwhelm the worker.

These insights lead to the following design opportunities:

- **[DO1]** Technology can be designed to help bridge the perspectives of the field team and Command through implicit and automatic information sharing.
- **[DO2]** WSAR workers could benefit from additional remote-communication modalities and information channels beyond just audio and text.
- **[DO3]** WSAR workers could benefit from additional opportunities for asynchronous communication and information sharing.

As well as the following design recommendations:

- **[DR1]** Anticipate network sparseness, and design communication modalities and information channels that take these into account.
- **[DR2]** New technologies should not burden or distract workers.
- **[DR3]** Communication modalities and information channels should be aggregated, to allow for easy viewing, searching, sorting, and comparisons.

In the next chapter, I build on these insights, design opportunities, and recommendations to present a system design focused on addressing the needs of the Command team. This system, called *RescueCASTR*, is designed to provide Command with enhanced awareness of the activities of field teams and the situation in the field.

4

DESIGN OF RESCUECASTR

In this chapter, I present a medium-fidelity prototype of an interface for the wilderness search and rescue (WSAR) command post. Called ***RescueCASTR***, or *Search and **Rescue** **C**ontextual **A**wareness **Str**eaming Platform*, this interface is designed to help Command keep track of field teams and their progresses, actions, statuses, and communications in a large WSAR operation. The goal is to explore ways to bridge the perspectives of Command and the field through new technologies and information streams. For this current work, I focus on exploring ways to provide Command with more implicit awareness of events and conditions in the field and the experiences of the field teams, so their decision making can be better reflective of and empathetic toward the experiences and needs of the field teams. RescueCASTR does this by exploring the idea of sending teams out to the field with at least one of their members wearing a body camera that streams live video or sequential photos periodically (e.g., once every five seconds) to Command, allowing Command to see the footage live and explore past footage.

Through the design of this interface, I further address the second research problem of my dissertation:

- **Research Problem 2:** We have a limited understanding of how remote collaboration technologies should be designed to better support building and maintaining a shared mental model in WSAR.

This chapter presents work that is currently (at the time of writing) in submission to the Association for Computing Machinery (ACM) Conference on Computer-Supported Cooperative Work and Social Computing (CSCW) and the Proceedings of the ACM on Human-Computer Interaction (PACMHCI) journal:

- **Jones, B.**, Tang, A., and Neustaedter, C. RescueCASTR: Exploring Photos and Live Streaming to Support Contextual Awareness in the Wilderness Search and Rescue Command Post. In submission to *ACM Conference on Computer-Supported Cooperative Work and Social Computing (CSCW)*.

4.1 DESIGN DIRECTIONS

The overarching challenge I tackle through the design of RescueCASTR is the challenge of building and maintaining a shared mental model. In tackling this challenge, I pursue all three of the design opportunities outlined in the previous chapter:

- **[DO1]** Technology can be designed to help bridge the perspectives of the field team and Command through implicit and automatic information sharing.

For this work, I primarily focus on the Command perspective; i.e., on helping Command better understand the activities of field teams and the events and conditions in the field through the perspective of the field teams. This itself is a big challenge, and thus I leave any pursuit of bringing the Command perspective to field teams for future work.

- **[DO2]** WSAR workers could benefit from additional remote-communication modalities and information channels beyond just audio and text.

In RescueCASTR, I introduce the ability for field teams to implicitly and automatically send visual information of their surroundings to Command through photo streams from body cameras worn by team leaders. In addition to this implicit information sharing, I also introduce the ability for field teams to attach photos (e.g., of clues found) to text messages they send to Command. Furthermore, I aggregate these new information streams with other existing information channels and sources, such as field teams' text messages, GPS locations, trail maps, satellite imagery, and information about radio dead zones, while displaying them together on a map and timeline view.

- **[DO3]** WSAR workers could benefit from additional opportunities for asynchronous communication and information sharing.

RescueCASTR provides Command users the ability to make use of the information channels asynchronously, without the requirement to interact live with field teams in the moment, as the information that comes in is recorded and stored in the system. The user can view a team's body-camera footage live, or explore past body-camera footage taken at a particular time or location later on in the operation. The user can do the same with field teams' message histories.

While pursuing these design opportunities, I follow all three of the design recommendations highlighted in the previous chapter:

- **[DR1]** Anticipate network sparseness, and design communication modalities and information channels that take these into account.

- **[DR2]** New technologies should not burden or distract workers.

- **[DR3]** Communication modalities and information channels should be aggregated, to allow for easy viewing, searching, sorting, and comparisons.

4.2 DESIGN PROCESS

My design process for RescueCASTR followed these five steps: (1) generate a list of low-level goals for the interface to satisfy, (2) generate a set of high-level early design ideas and sketches, (3) narrow in to focus on a smaller set of these high-level ideas, (4) create refined sketches and a generate a more complete list of design features, and (5) implement a medium-fidelity prototype.

In designing RescueCASTR, I generated a list of lower-level goals for the interface to satisfy. These goals are based on the findings from the study in the previous chapter. In particular, they are based on (1) the activities I observed Command workers conducting in the mock search, and (2) the activities that interview participants told me Command workers aim to achieve in their work:

- Know where field teams are presently located
- Know where field teams have been (past)
- Know where teams are going (future)
- Know what field teams are facing in the present moment
- Know what a field team faced at a particular past moment
- Know what a field team faced at a particular location
- Keep track of incoming messages from field teams
- Receive a message from a field team
- Know what time a message was sent by a team

- Know where a team was located when they sent a message
- Know what a team was doing when they sent a message
- Know what a team's surroundings were when they sent a message
- Get a quick status update from teams
- Check to see if field teams and their members are okay (physically)
- View a location on the map from different perspectives

Starting with this list, I then began to brainstorm technology solutions for making these goals easier to achieve. I led a set of brainstorming sessions with my PhD supervisors to discuss ideas and eventually narrow in on a single design to refine and iterate on. In the first brainstorming session, I developed a list of potential technology solutions:

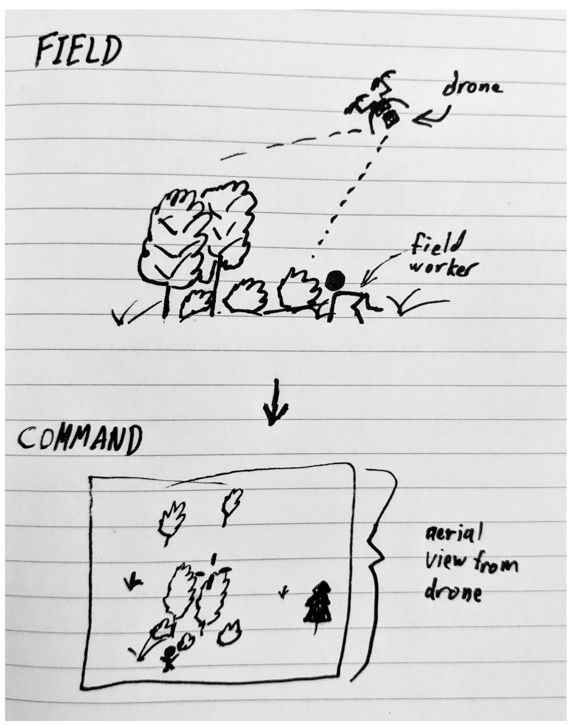

Figure 10: An interface sketch of a drone-video-conferencing system for WSAR.

- A drone-video-conferencing system (similar to [53]) through which a Command worker can view a third-person view of each of the field teams, and/or explore the field location on their own (e.g., Figure 10).

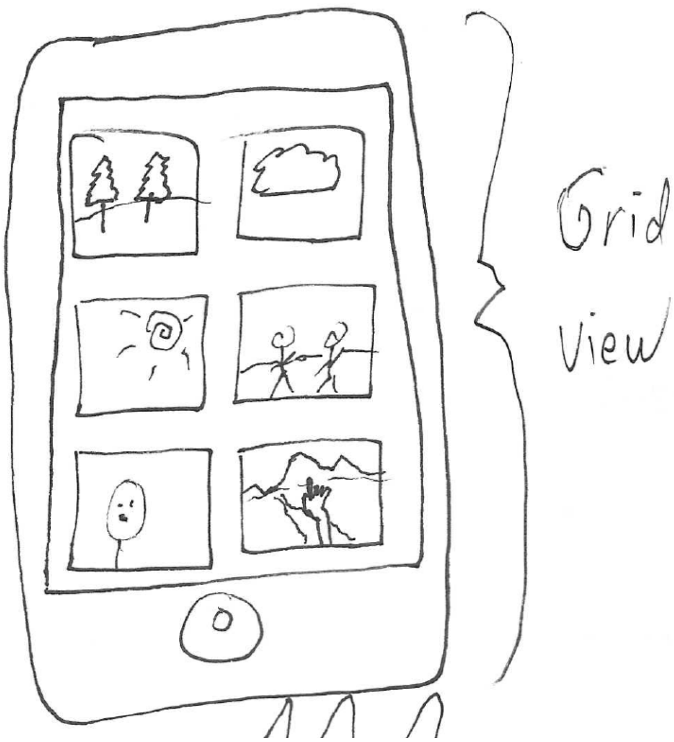

Figure 11: An interface sketch of a multi-way mobile-video-conferencing system for WSAR. This sketch shows a single user's (e.g., the Command user's) interface view.

- A multi-way mobile-video-conferencing system (similar to [79]; e.g., Figure 11), allowing multiple outdoor users (e.g., WSAR field teams) to stream video to and communicate with a single indoor user (e.g., a WSAR Command worker).
- A body-camera system, worn by field teams, that automatically streams live video or sequential photos (e.g., once every few seconds, few minutes, at key locations, or at key points in time) to Command whenever it has a network connection with the command post.
- A map-and-timeline system, aggregating all (or most) of the information a WSAR response team has on hand about the incident (e.g., the lost person's last-known location, last-seen location, clues from the field, locations and activities of field teams, etc.) into one interface, so it can be viewed geospatially (in relation to the geographic environment) and temporally (in relation to time).

I ultimately chose to focus on the last two ideas, and design a system that incorporates both passive body-camera video/photo streaming and aggregation of multiple information sources and channels. I then began to sketch potential interface designs.

Alharthi et al. [1, 2] found that much of SAR planning and discussion is centred around maps, as they provide an effective means to record key information about the search and communicate it with team members. Given this, I decided to create an interface that focuses on displaying information in relation to a map of the search area.

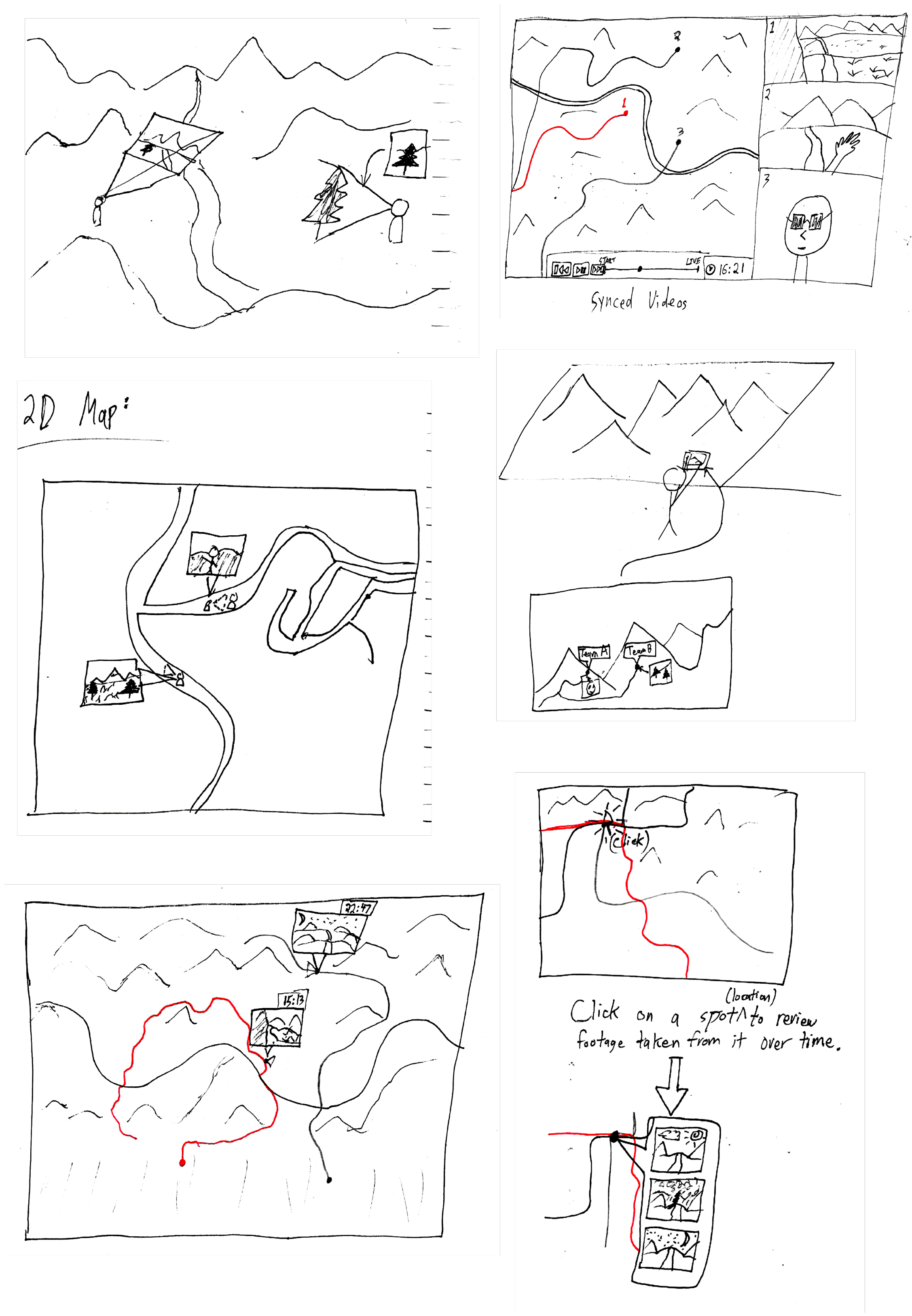

Figure 12: A set of early interface sketches I drew for the RescueCASTR Command interface.

I then narrowed in on a set of features to design and implement in RescueCASTR for each of the design goals listed above:

Goal	**Feature(s)**
Know where field teams are presently located	• Live team locations on map
Know where field teams have been (past)	• Teams' paths of travel shown on map as solid lines
Know where teams are going (future)	• Teams' future paths of travel (based on their tasks assignments) shown on map as dotted lines
Know what field teams are facing in the present moment	• Ability to preview (as thumbnail image over the team's icon on the map) the live stream of the team leader's body camera • Ability to full-screen this live stream image to watch it in greater detail
Know what a field team faced at a particular past moment	• Ability to select a point in time on the timeline to see a team's body-camera footage at that moment
Know what a field team faced at a particular location	• Ability to select a location on a team's path on the map to view their body-camera footage at that location
Keep track of incoming messages from field teams	• Automatic logging of incoming messages from field teams
Receive a message from a field team	• Messaging threads
Know what time a message was sent by a team	• Selecting a message in the message thread displays the time it was sent, and highlights it on the timeline
Know where a team was located when they sent a message	• Selecting a message shows its location on the map
Know what a team was doing when they sent a message	• Messages show up on both the map and timeline as icons, indicating where and when they were sent. The user can hover over the team's path on the map or over the timeline, near a message icon, to see what the team's body camera was capturing around the time/location the message was sent
Know what a team's surroundings were when they sent a message	• Selecting a message shows a preview of the team leader's body-camera footage when the message was sent
Get a quick status update from teams	• Selecting a team shows their present location, a live stream from the team leader's body camera, the path they travelled, and their future path of travel (based on their task assignment)
Check to see if field teams and their members are okay (physically)	• Selecting a team shows their live body-camera footage, which can indicate the team's status • Viewing a team on the map can give an indication of if they are moving

View a location on the map from different perspectives	• 3D map view gives the user the ability to view a location from different perspectives • The user can select the paths of teams that have crossed through a location, to view that location from different viewpoints and at different points in time
Communicate with a field team	• A messaging thread for each field team

Figure 13: A body camera worn by the field team leader.

4.3 SYSTEM DESIGN

The goal of RescueCASTR is to explore how information aggregation and body cameras can be used to give Command better awareness of events and conditions in the field. Field teams carry with them a wearable camera that the team leader or one of the team's members wears on their jacket, helmet, or backpack strap (Figure 13). This camera takes sequential photos, once every few seconds, showing a forward-facing visual picture of the team's surrounding environment, the path ahead, and the team's actions if the team member wearing the camera is at the back of the group. The camera is connected to a computing device such as a smartphone or tablet connected to a cellular network and/or a digital radio system (e.g., a mesh-networked system such as goTenna Pro [112]), and whenever there is a connection with Command, the device sends the photos to Command immediately after they are shot. If the team does not have a connection with Command (e.g., the team is in a radio or cellular dead zone), the photos are cached locally on the field team's device and sent to Command immediately after the team regains a connection with Command. The camera footage is meant to provide Command with extra contextual information of teams' activities to reduce explicit communication requests (e.g., requesting the field teams to respond on the radio or to a text message).

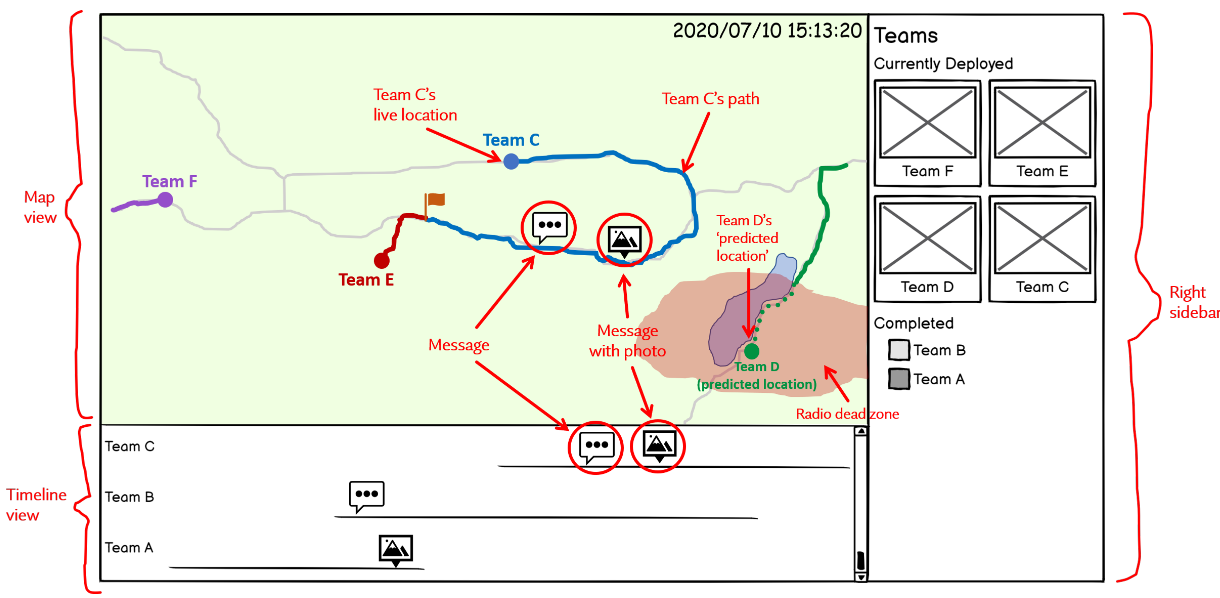

Figure 14: A schematic of the RescueCASTR Command interface.

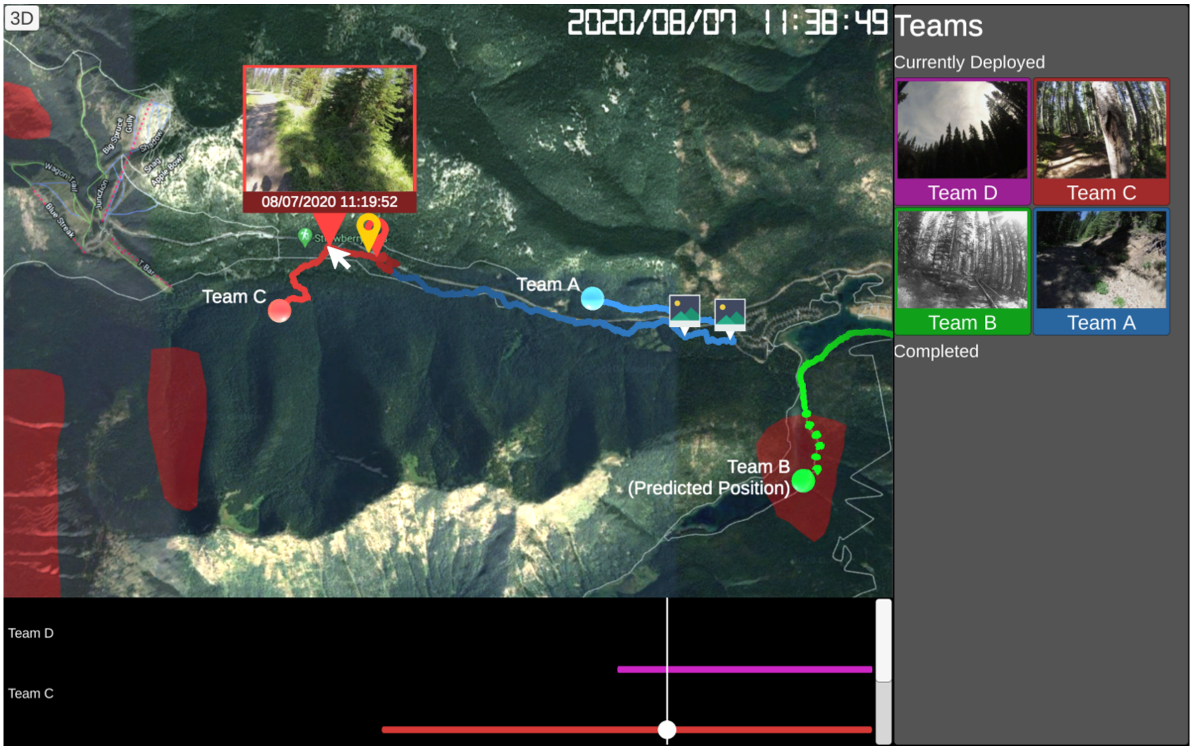

Figure 15: The RescueCASTR Command interface, default view.

This footage is displayed on Command's interface, shown in Figure 14 as a schematic for simplicity and easier understanding, and Figure 15 as a screenshot of the actual system. This interface runs on a desktop or laptop computer inside the Command vehicle, displays a map of the search terrain, and presents information about the current status of the search as well as the data collected and recorded via field teams' actions throughout the search operation. The following data are presented:

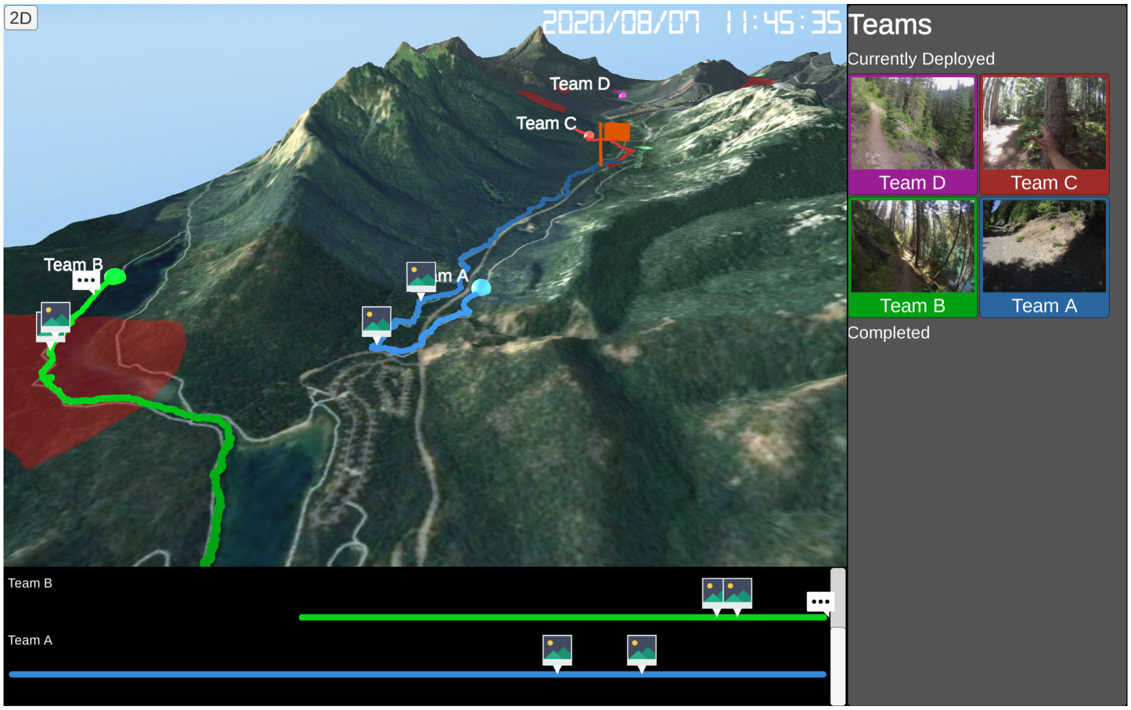

Figure 16: The map of the search terrain displayed in '3D mode'.

- **Map View:** Displays a map of the search area, overlaid with a satellite image. The user can pan the map via clicking and dragging with the mouse, and zoom in and out using the mouse wheel. The user can also toggle the map to '3D mode' to get a 3D perspective of the area, see the terrain height, and rotate to view from different perspectives (see Figure 16). The map displays teams' paths, current locations, messages, locations of radio dead zones, and features such as trails and bodies of water. For example, Figure 15 shows four teams presently deployed in the field (Team A, B, C, and D as shown in the figure), three of which are visible on the map along with traces of their paths, and one that is presently off-screen on the map.

Figure 17: Displaying a full-screen view of a team's body-camera footage.

- **Team Paths:** Teams' routes of travel are shown on the map as coloured paths. As an example, Figure 15 shows Team A's path with a blue line, Team B's path with a green line, and Team C's path with a red line. These paths come from teams' GPS locations, which are captured every few seconds. When a team is in a radio dead zone, their predicted route in the dead zone is represented as a dotted path (e.g., Team B's path inside a radio dead zone in Figure 15). Hovering the cursor over the team's path reveals what their body camera was capturing at that location (e.g., Figure 15), as well as a needle on the timeline view (bottom) indicating what point in time they were at that location. Clicking on the path at that location displays the image in full screen (e.g., Figure 17).
- **Teams' Live Locations:** A dot on the team's path indicates their current location. If a team is in a radio dead zone (i.e., out of telecommunications contact with

Command), this dot indicates their 'predicted location', which is calculated from their assigned path of travel, their average speed of movement, and their last known location.

- **Radio Dead Zones:** Shown as red shaded areas on the map, these indicate areas where field teams are not likely to have telecommunications contact with Command. When a team is in a dead zone, their predicted location is displayed. Once a team exits a dead zone, all of their body-camera footage from inside the dead zone, plus the messages they have sent within the dead zone, become visible on the interface. For example, Figure 15 illustrates that Teams A and C currently have live contact with Command, but Team B is in a dead zone, and therefore the location presented on the map for Team B is a predicted location.

- **Timeline:** On the bottom of the screen, the timeline displays a temporal representation of the same data that are displayed on the map. Messages are displayed on the timeline using the same icons as on the map. Hovering the cursor over a team's timeline on the timeline view reveals what their body camera was capturing at that point in time, as well as a dot on the map indicating what their location was at that time. Clicking on the timeline reveals a full-screen view of the image (e.g., Figure 17), similar to clicking on a team's path on the map.

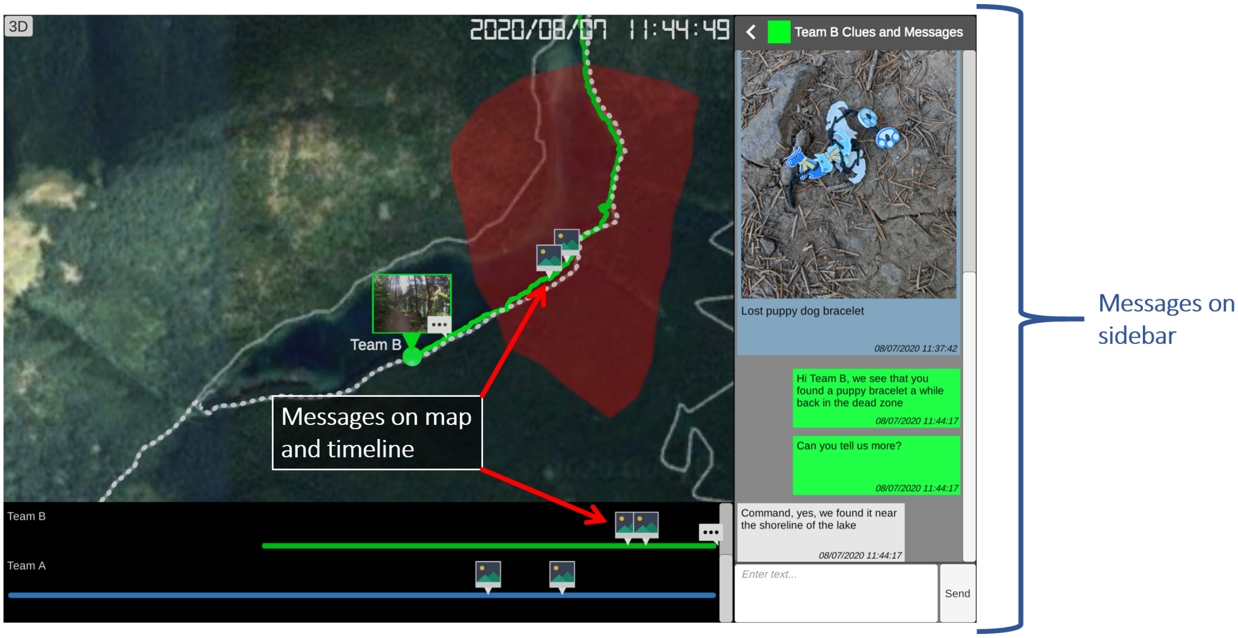

Figure 18: The messages thread (right sidebar) for Team B, showing a messaging thread between Team B and Command. Messages are also indicated on the map and timeline as icons.

- **Messages:** In addition to implicit information sharing (body camera footage, GPS positions, etc.), RescueCASTR also provides the ability for field teams to explicitly communicate with Command via text messages. Messages are displayed on the map and timeline views (indicating the locations and times they were sent), as well as in the team's messages thread (Figure 18). A message can also contain an attached photo (e.g., a clue photo), and messages with photos are indicated as image icons on the map and timeline views. When a team send a message inside a radio dead zone, it is cached on their device and sent to Command as soon as they regain connection.

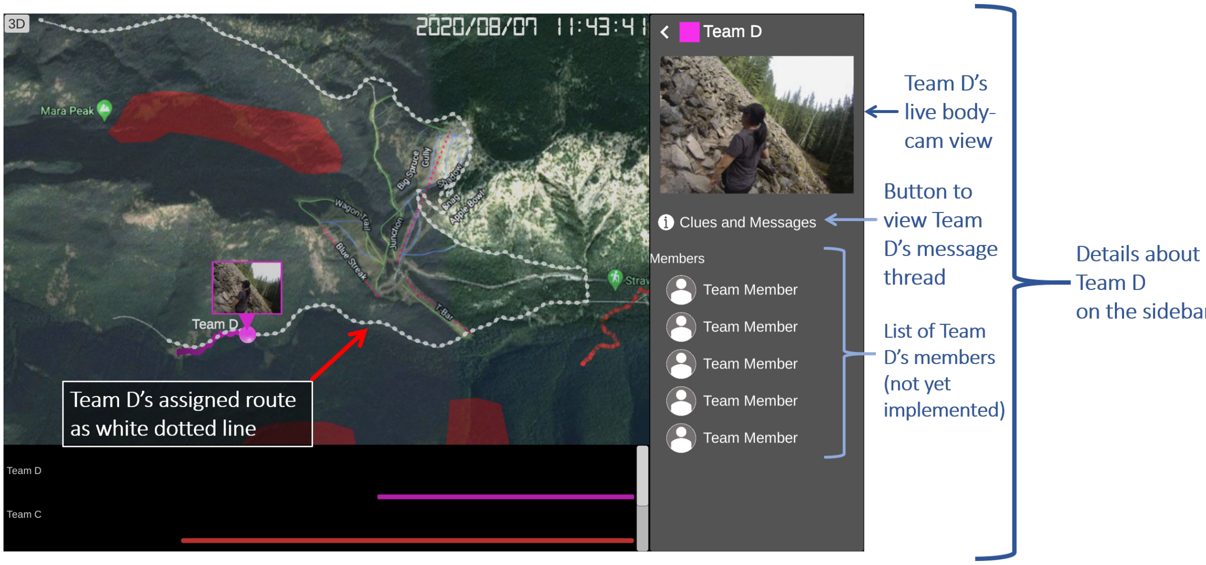

Figure 19: Selecting a team displays (a) more details and options for the team on the right sidebar, and (b) their assigned search path as a white dotted line on the map.

- **Right Sidebar:** Reveals details about the field teams, including which ones are currently deployed and which ones have finished their assignments. For the deployed teams, their most recent body-camera images are shown. Clicking on a field team's icon reveals more details about them (Figure 19), including a list of the team's members (not implemented in the current iteration of the prototype), a larger view of their most recent body-camera image, their assigned path of travel (revealed on the map as a white dotted line; e.g., Figures 17 and 19) and an option to pull up a messages thread (Figure 18) in which the Command user can view the team's previous messages, as well as send them new messages.

This system concept assumes that when field teams have a connection with Command, the connection has sufficient bandwidth to send low-resolution photos to Command once every few seconds. While this may not be the case everywhere today, it is expected that networking technologies will improve in the future.

A video demonstration of the RescueCASTR Command interface is included with this dissertation as supplementary material, and can also be found here: https://tinyurl.com/rescuecastr-demo.

4.4 SIMULATION DESIGN

While the RescueCASTR interface is designed to work with incoming live video/photo streams from multiple nodes (i.e., body cameras attached to field team leaders) streaming via a network connection (e.g., a cellular, digital radio, or mesh network), the current implementation of the system runs with simulated data, and plays back pre-recorded scenarios as if live body-camera footage was streaming in. It is thus a medium-fidelity prototype. Simulation playback allows me to evaluate the current iteration of RescueCASTR by creating a set of simulated scenarios in which multiple field teams are scattered and moving around a search area, and playing back those scenarios in the prototype. This is the approach I took in evaluating RescueCASTR (more details on this study are presented in the next chapter).

4.5 IMPLEMENTATION

The RescueCASTR prototype was implemented using the Unity Engine[1]. There were two parts of the implementation of the current medium-fidelity prototype of RescueCASTR: (1) the implementation of the interface itself, and (2) the implementation of simulation playback. I implemented both parts side-by-side.

1 https://unity.com/

I used a tool called 3D Map Generator[2] to create 3D terrain maps textured with satellite imagery. I created terrain maps of three locations in British Columbia, Canada: (1) Golden Ears Provincial Park, (2) Pacific Spirit Regional Park (in Metro Vancouver), and (3) E.C. Manning Provincial Park. I used these three locations for the three study scenarios I created for the user study (more information about this in the next chapter). I imported each of these terrain maps into a Unity scene, and for each of these scenes I created mappings to translate GPS coordinates and altitude measurements to scene positions, so that I could automatically translate a coordinate from a GPS track recording (in '.GPX' format) into a corresponding position in the Unity scene matching the location with respect to the terrain model. I then implemented click-to-drag, click-to-rotate, and mouse-wheel-to-zoom controls for the view of the terrain map.

To record the study scenarios, I visited all three of the above-mentioned locations and recorded hiking footage spanning 12 hours across 35-40 kilometres of travel. To record this footage, I strapped on a GoPro camera to my backpack strap (similar to Figure 13), set it to record in timelapse mode (i.e., a timestamped photo every two to five seconds), and used my phone to record a timestamped GPS track (in '.GPX' format, with waypoints taken every few seconds) at the same time. Each photo-timelapse recording taken by my GoPro was paired with a corresponding GPS-track recording taken by my phone. In each of the three locations, I took multiple GPS/photo-timelapse recordings, each representing a simulated field team. I then took these recordings, uploaded them to a University of Calgary Computer Science research server, and organized them into directories based on scenario and field team.

For each scenario that was played back by the prototype, a 'scenario start time' was defined. This was a date and time for which the scenario would start to play back. When

2 https://www.3d-map-generator.com/

a scenario began to play back, the clock on the interface would begin to tick in realtime starting from this start time. For each team recording, a 'team start time' was defined. This was defined as the time that the team started moving and broadcasting a livestream in the scenario, and thus the start time of the recording was offset to this time. If a recording's start time was set to before the scenario start time, playback of the recording would begin part way through.

Each team recording also had an 'assigned route' and 'radio dead zones' defined. The assigned route was defined as the route that the team was supposed to take in their assignment, which may not necessarily match the route they were actually taking. The assigned route was a GPS track (in '.GPX' format), similar to the GPS track of the team's actual route, but without timestamps and with fewer waypoints. Radio dead zones were defined simply as blocks of time during which the interface would present the team as being 'out of radio contact', and thus would not display an updated body-camera image or GPS location. Instead during these time blocks, the interface would display a 'predicted location' for the team. This predicted location was calculated based on the team's 'last known position' before entering the radio dead zone, their assigned route, and their average speed of movement, and assumed that the team would continue moving along their assigned route at the same speed.

Messages were also implemented into the interface such that the user had a one-to-one message thread with each of the field teams in the simulation. Messages included both text-only messages and messages containing text plus an attached photo (e.g., clues). Each message had a timestamp included, so that it could also show up on the timeline and map in its corresponding location/timepoint. Messages from a field team were included in that team's simulation recording, and programmed so that they would 'appear' on the interface at a given time in the simulation playback. This was to simulate, for example, the team finding clues or sending text messages at specific locations or timepoints.

Lastly, I implemented a separate 'Wizard-of-Oz' interface, allowing me as the study investigator to send text messages 'as a specific field team' to the RescueCASTR Command interface at any time during the simulation playback, to add more interactivity to the study scenarios and allow study participants to act as if they were communicating directly back-and-forth with the field teams during the study. These messages would appear on the interface alongside the messages that are 'pre-programmed' in the simulation to appear at specific timepoints.

The source code of the RescueCASTR prototype is included with this dissertation as supplementary material, and can also be found here: `https://github.com/ricelab/RescueCASTR`.

4.6 SUMMARY

In this chapter, I presented RescueCASTR, an interface for the WSAR command post, designed to help WSAR commanders maintain a mental model of key aspects of a search response. RescueCASTR does this by aggregating information from multiple data sources into a single interface, presenting that information geospatially (in relation to a map of the search area) and temporally (in relation to a timeline of the WSAR response). The interface also focuses on field teams, and aims to provide Command workers with heightened contextual awareness of their statuses, surroundings, and activities through the displaying and logging of body-camera footage, GPS locations, and messages. This interface is designed to not provide too much burden on field workers (as the body cameras stream photos passively without user intervention), as well as to provide use while teams are on- and off-line. I also described the design process leading to the RescueCASTR interface, as discussed the use of simulated scenarios in the current prototype of RescueCASTR.

In the next chapter, I present a remote user study to evaluate the RescueCASTR interface through simulated use-case scenarios.

5

REMOTE SIMULATION USER STUDY OF RESCUECASTR

This chapter presents a detailed description of the user study I conducted with wilderness search and rescue (WSAR) workers to evaluate the RescueCASTR interface and to understand the potential opportunities that a system like RescueCASTR could provide to WSAR commanders. These opportunities include the potential for WSAR managers to use the system as part of their workflow in building and maintaining a mental model of the operation, as well as in projecting ahead and planning future decisions. This study was approved by the Conjoint Faculties Research Ethics Board at the University of Calgary. The materials used for this study are in Appendix C.

My findings illustrate that the awareness provided by the camera footage could give additional confidence and comfort to Command, as well as reduce the need for explicit communications. However, it could also impact workers' existing roles and responsibilities, shifting the burden of responsibility toward Command. This demonstrates that, while wearable-camera footage could be beneficial to Command, they need to have the tools and means to narrow their focus within the abundance of information provided. Furthermore, camera streams should not be thought of as a replacement for more direct communications, but rather as another tool available to help Command supplement their understanding of events in the field and narrow their focus.

Through evaluation of the RescueCASTR interface, reflection on the choices made in the design process, and discussion of new design opportunities, this study further addresses the second research problem of my dissertation:

- **Research Problem 2:** We have a limited understanding of how remote collaboration technologies should be designed to better support building and maintaining a shared mental model in WSAR.

In addition, through discussion of potential opportunities and challenges that RescueCASTR could provide to WSAR workers, as well as potential impacts on WSAR work practices, this study addresses the third research problem of my dissertation:

- **Research Problem 3:** We have a limited understanding of how new remote collaboration technologies could impact WSAR work practices, including how WSAR workers collaborate and maintain a shared mental model across distances.

This chapter presents work that is currently (at the time of writing) in submission to the Association for Computing Machinery (ACM) Conference on Computer-Supported Cooperative Work and Social Computing (CSCW) and the Proceedings of the ACM on Human-Computer Interaction (PACMHCI) journal:

- **Jones, B.**, Tang, A., and Neustaedter, C. RescueCASTR: Exploring Photos and Live Streaming to Support Contextual Awareness in the Wilderness Search and Rescue Command Post. In submission to *ACM Conference on Computer-Supported Cooperative Work and Social Computing (CSCW)*.

5.1 STUDY METHOD

I conducted a remote user study with WSAR managers from across Canada. The goal of this study was to get an understanding of the potential opportunities and challenges of live wearable-camera streaming from field teams to the command post. I focused this study around the following research questions:

1. To what extent would WSAR managers be able to understand the information presented on the interface?
2. How would WSAR managers use RescueCASTR to build a mental model of field teams' statuses and actions?
3. How might a system like RescueCASTR impact WSAR workers' existing roles and responsibilities?

5.1.1 *Participants and Recruitment*

I recruited 11 WSAR workers, including 10 WSAR managers and one field team leader, from volunteer SAR agencies in Canada. Ten participants were from agencies in Western Canada and one was from an agency in Eastern Canada. I recruited WSAR workers by contacting SAR agencies and provincial organizations representing SAR agencies, as well as through social media and my existing contacts working in WSAR. Participants were aged 27-63 (M=46.9, SD=11.6), had between one and 20 years (M=9.2, SD=5.3) of experience working in WSAR, and responded to between nine and 43 callouts (M=22.2, SD=11.7) on average per year. The ten WSAR managers had between one and 15 years (M=4.9, SD=4.2) of experience working in the WSAR command post.

5.1.2 *Protocol: Simulated WSAR Scenarios*

The study took place over a video call due to research restrictions on in-person studies in 2020 as a result of the COVID-19 pandemic. A prototype of the RescueCASTR Command interface was deployed to a web page that ran on a web browser on the participant's computer while they shared their screen to the study investigator via a Zoom call. The prototype displayed three mock WSAR scenarios, where each simulated live footage and location feeds from field teams deployed in a search area. Participants were asked to imagine that the data on the interface was live data from a real WSAR incident, and to imagine themselves in the Command post using this interface on a desktop machine as they explored the simulated live camera feeds and streaming information coming from the field teams. I developed the three scenarios based on real incidents that WSAR workers shared in the investigative study presented in Chapter 3. Prior to this study, I sent the scenarios to WSAR managers to get feedback on their realism, and iterated on them a few times before arriving at these final scenario designs. For each scenario, I gave participants a 'scenario sheet' document that described the scenario (for these, please refer to Appendix C.10).

- ***Scenario 1: Checking the Statuses of Teams.*** In this scenario, the participant was asked to do a routine checkup of the field teams' statuses, by checking the live camera footage. Participants were asked to make sure that all teams were safe (e.g., that nobody was injured), that they were on track to completing their assignments. There were four teams deployed in the field, one of which was in a radio dead zone at the start of the simulation. About 3.5 minutes in, this team stepped out of the radio dead zone and regained contact with Command.

- ***Scenario 2: New Information from the Lost Person's Family.*** In this scenario, a lost child's father comes to the Command post with new information about his child. The participant has to explore the past footage and messages from teams on the interface to see if there is anything relevant to the new information given by the lost child's father. There are three teams deployed in the field, all of whom have radio contact with Command.

- ***Scenario 3: Understanding Where a Team Landed.*** In this scenario, there is one team deployed via helicopter to the base of a mountain. However, the team leader messages Command telling them that they might not be where they should be, as poor weather conditions may have made it impossible for the helicopter to land near the mountain. The participant is to (a) check if the team is at (or near) the mountain, and (b) if they are not, give them instructions on how to get there.

Each scenario lasted between five and 20 minutes. During these scenarios, I asked participants to 'think aloud', or to describe what they were doing and why, so I could understand their thought processes while using the interface. During moments when they were silent, I used prompts to gauge their thoughts. To see a sample list of some of these prompts, please refer to Appendix C.4.

Rather than simulating a complete search response from start to finish, each scenario placed the participant in the middle of an ongoing response, and had them complete some of the smaller routine tasks that they would perform as a SAR manager or other member working in the Command post. I took this 'in the middle of the search' approach in order to assess the efficacy of the tool in allowing SAR managers to perform these tasks while also having them explore a variety of use cases within a limited time period.

Simulated WSAR Data. To seed the system with data, I pre-recorded 12 hours of hiking timelapse footage (i.e., a photo once every two or five seconds), across 35-40 kilometres of travel, using a GoPro camera attached to my backpack strap. This footage was captured in two mountainous provincial parks and one large forested urban park where each contained a network of hiking trails. This footage was used as the simulated 'live' footage from the field teams in the study scenarios. Footage was recorded for eight moving teams in total, with each team's footage lasting from 30 minutes to two hours and covering a path of between one and five kilometres. Even though participants spent only five to 20 minutes per scenario, the longer footage ensured that there was a lot of 'past data' for them to explore on the interface via hovering their cursor over teams' paths and timelines.

'Wizard of Oz' Message Responses. During each scenario, when the participant used the interface to send text messages to the field teams, the study investigator played 'Wizard of Oz' to fulfill message responses from the teams in order to add additional interactivity. The study investigator used his own interface to type responses to the participant's messages, which would then show up as a message from the field team on the RescueCASTR interface.

5.1.3 *Interviews*

After completing the three scenarios, I conducted 15- to 30-minute post-scenario semi-structured interviews with participants to get an understanding of their work in the Command post, challenges they face in communicating with and maintaining awareness of field teams, and their interactions with and perceptions of the RescueCASTR interface. I started each interview by first asking them broad questions related to their work as SAR managers; e.g., *"Please describe a real incident you responded to as a SAR worker in* *the Command post in which maintaining communication with and awareness of field teams was particularly challenging. What made it challenging?"* I then narrowed the scope, focusing more on the RescueCASTR system concept and Command interface; e.g., *"If you had a fully-functional version of the RescueCASTR interface to use during that incident, how do you imagine it might have played out?"* The full set of questions I asked is in Appendix C.5.

5.1.4 *Data Analysis*

The data were analyzed using open, axial, then selective coding. When analyzing and coding the data, I was particularly interested in understanding the following:

- How did participants use the camera footage and other data on the interface to establish and maintain *workspace awareness* (WA) [44, 45]? How did certain elements of the interface design or the information-sharing modalities in the interface support or hinder this? In particular, I was interested in understanding how participants used the interface to answer the *who/what/where/when/how* questions of WA – questions such as "*who* is deployed?", "*what* are they doing?", "*what* have they found?", "*what* are they seeing?", "*what* have they seen?", "*where* are they?", "*where* have they been?", "*when* have they been there?", "*when* will a team reach a certain area?", and "*how* did they perform certain actions?"
- How did participants use the camera footage and other data on the interface to establish and maintain *situation awareness* (SA) [30–32]? How did certain elements of the interface design or the information-sharing modalities in the interface support or hinder this? In particular, I was interested in understanding how participants used the interface to attain SA across all three levels (*perception*, *comprehension*, and

projection). For example, were they able to *perceive* the contents of the body-camera footage or the contents of teams' messages? Were they able to *comprehend* their meaning, and infer understanding of the current situation or status of the response from them? Lastly, were they able to use that understanding to *project* ahead and plan future actions in the response?

- What are the potential challenges and opportunities, within the context of WSAR, of aggregating multiple data sources into a single location and presenting relationships between various representations of the data (e.g., relating data on a map to the same data on a timeline)? Could such an approach support participants in establishing WA and SA? What challenges might such an approach introduce?

Open codes included categories such as 'footage providing awareness of features in the field', 'footage providing awareness of a team's progress', 'reviewing past data to plan future actions', and 'micromanaging the field teams' actions'. My axial codes included categories such as 'footage enhancing awareness', 'use of live footage', 'use of past footage', and 'decision making'. During the selective-coding phase, I saw themes emerge around the footage enhancing Command's awareness and mental model, the impact of camera footage on workers' roles and responsibilities, and Command's need to narrow their focus in an abundance of camera footage. I completed most of the coding, but the codes were reviewed collectively and iteratively by my supervisors, as well as in a group session with other research colleagues. To see a complete listing of the codes, please refer to Appendix D.

I now describe the study findings. Participants' interview quotes and vignettes illustrating their interactions with the RescueCASTR interface are listed with '*P#*' indicating the participant ID.

The findings are split into five subsections. First, I report on the use of body-camera footage to aid Command in planning and maintaining awareness. I then report on how commanders used the footage in combination with other data sources such as GPS tracks, messages, and mapping data (trail maps, satellite imagery, terrain data) to triangulate it in attempt to infer a complete story. Next, I report insights on how new implicit information sources such as body-camera footage could impact WSAR workers existing roles, responsibilities, and work practices. I then report on how participants made asynchronous use of past data (i.e., as opposed to synchronous use of live incoming data). Finally, I touch on privacy, pragmatic, and usability concerns raised by participants.

5.2.1 *Camera Footage Could Enhance Command's Awareness and Aid in Planning*

Participants found utility in the camera views within RescueCASTR and stated that the views could provide extra awareness of field teams' situations and activities to Command. The camera views could boost the agency's shared mental model, as they provide Command with a visual awareness similar to that of teams in the field.

> *"I definitely see a lot of value in in having that real time data in being able to see through their eyes." – P8*

Awareness of Conditions in the Field. In particular, participants found utility in the additional awareness of features in the field, such as tree and vegetation cover, the nature of the path (e.g., wide, narrow, steep, flat, bumpy, smooth, etc.), the steepness of the terrain, and the proximity of geographic features such as lakes and rivers. They said this awareness could help them in understanding what a team is facing, and in addition help them with future decision-making and planning activities.

> *"It probably would have been extremely helpful because of the weather challenges we had and [in] getting up-to-date overhead imaging of the area we were in. [Rescue-CASTR] would have helped in some of the areas to identify what kind of coverage we had, like vegetation coverage." – P4 (when asked about how RescueCASTR might have affected a past incident he was involved in)*

Seeing the features of the field via the body-camera views could also help in that they allow Command to make their own determination about field conditions, rather than having to rely on radio-based verbal reports from field teams. In turn, these are tedious to give, as they are plainly obvious to field teams (akin to reporting on the nature of the weather).

> *"I can make my own interpretations. I mean, there's a certain degree of cost we have with team members [in] how they would describe their environment and all the rest of it, [and] it's just kind of nice to see for my own eyes. You know what kind of environment that they are truly in." – P6*

In some cases, Command being able to interpret the situation on their own could save time. It may not always be the case that a member of a field team has the knowledge or skills to make some of these judgement calls themselves; but someone at the Command post might have the expertise to make a better judgement.

> *"Some people will underplay or overplay the difficulty of the terrain that they're in. And [they say] 'oh yeah, you can easily get a quad up here', when in fact it's not easy to get a quad up [there], that kinda stuff." – P6*

Awareness of features in the field could also potentially help SAR managers guide teams in their assignments when they are currently deployed. For example, participants mentioned that if they are able to observe the current weather and ground conditions that teams are facing, they might be able to suggest to the team to traverse an easier or safer area, or an area where they might be more likely to find the lost person.

> *"Being able to have eyes up on just how bad the conditions were that the teams were working in, the manager at that time may have sent extra resources or maybe changed the way of following the terrain. When I said 'okay, well, you know, go up higher, you know, stay down low, keep following the creek'. It [would] make me want to make some different choices. Just because you have more information to make decisions on."*
> *– P5 (when describing how RescueCASTR might have affected a past incident he was involved in)*

During Scenario 1, I witnessed P9 scanning the footage to remain aware of the current safety and situation of a team traversing through a steep mountainside, and to plan ahead for how to keep them safe in case the situation changed. For example, as he was scanning the imagery, he said *"looking at these pictures here, I wouldn't have sent these people up into the field, they're wearing improper footwear."* While pointing at a particularly steep section of the team's path containing large smooth boulders, he said *"this area right here, going back there, would be something that I would make sure the team [is] doing a good recon [assessment of their own safety], especially if rain came in [...] this could be very slippery."* This is information that he, as a manager, would be able to make use of for instructing or guiding the field teams in making better decisions in the current moment, for deciding what clothing and resources future teams being deployed to the same area should take with them, and for planning ahead for what to do in case the situation changes at that particular location (e.g., the temperature drops, rain falls, someone is injured, etc.). When I asked about these actions later during the interview phase, P9 said that he found value in being able to think about these decisions in realtime, with a visual picture of the team's situation updating in realtime.

In the same scenario, I also witnessed P4 scanning his cursor over a team's path along a lake to scan the team's camera footage taken along that path, in order to determine what the water was like along the path. P4 determined that the water was calm and still. Given this and the fact that the team found a puppy-dog bracelet along the water, which was a relevant clue to the lost child in the scenario, P4 determined that the lost child may have gone for a swim in the water. He then stated that his next step as a SAR manager in this case would be to deploy a team with diving gear to that location.

While Command has access to maps and satellite images of the search terrain, these are not always up to date. For example, participants pointed out that there could be paths that are non-existent on Command's map, or conversely, paths that show up on Command's map that are non-existent in the field. Additionally, the satellite images only show an aerial snapshot of the terrain taken at a point in the past. They do not show details of what the terrain looks like close-up, in the present moment, in current circumstances (e.g., weather, snow, mud, and/or water buildup, etc.) and from the perspective of the field teams. Participants pointed out that the body-camera footage allows Command to see a snapshot of this information, albeit lower fidelity than what the teams actually experience with their own eyes. This information can give the SAR agency a more consistent shared mental model, as it could enhance Command's understanding of what the field teams are experiencing.

"I think it's going to help me with planning considerations like this team here... Knowing there's a trail that's not on our map means [there are] probably a number of trails not on our map." – P8

Participants also mentioned that awareness of features in the field could help managers plan for the future. This planning could occur both live (when teams are deployed) and at the end of an operational period, when the teams sent out to the field finish their assignments. The SAR management team could review past footage in certain parts of the search area to determine what strategies to take when they deploy teams to those areas in the next operational period.

"Being able to get that live view of what the terrain was like would really help with planning the second or third or fourth operational periods [the next stages of the operation]." – P8

For some of this planning, they may need to make a judgement that relies on knowledge of the present ground or weather conditions of a certain area. For example, they may need to know if they can deploy a field team to a location via an all-terrain vehicle (ATV), whether a team needs to take snowshoes with them, if it is safe to land a helicopter in an area, or if a rescue team can carry a stretcher with a wheel to an area if they find the lost person there. Some SAR managers mentioned that they could explore the camera footage on the map to help them determine these things.

In addition, SAR managers pointed out that some situations could benefit from a second look by someone with specialized expertise, such as a medical doctor or avalanche technician. For example, one SAR manager pointed out that an avalanche technician could examine body-camera footage of a scene to assess the risk level of an avalanche occurring, as well as to provide necessary advice to the field team.

"We're doing training around avalanche, but [...] we have to get boots on the ground, and then you're either waiting there for an avalanche technician to fly in, or you know, you might try [to go in]. But if we've got a video camera that can take pictures, then [the avalanche technician at Command] can make some assumptions based on what he's seeing because he already will have a lot of forecast data. And we [Command] can provide info: 'here we see crowns, we can see fresh snow', and we can show the path of the avalanche, what classification it is... and we can say 'no, you can't go in, we'll have to do something in the area to make it safe'." – P9

He also pointed out that a paramedic on scene at the command post could use a team's body-camera footage to perform an early assessment of the subject, give advice to the team on first-aid interventions, or assess the subject's health and situation in advance of their arrival at the ambulance.

Awareness of a Team's Progress. In addition to awareness of features in the field, our participants pointed out that the camera footage could also provide Command awareness of a field team's progress – or simply, it could provide awareness that a team is making progress.

"On an immediate day to day operation, I think the utility's in the fact that there's movement [that I can see movement]. I really like that. I can see the teams are moving." – P1

With today's technology, SAR managers are usually aware of a team making progress only when they do a radio check with Command. However, with body-camera footage, as long as a team has a stable connection with Command, participants said that Command could see a team making progress through changes to their live camera footage. At minimum, this could serve as sort of a 'heartbeat' for the team, providing basic awareness that the team is still okay. Participants mentioned that seeing the contents of the camera footage change in realtime could give Command additional confidence that a team is safe.

> *"There's a strong safety aspect here of being able to see what the teams are up to. And what the environments are like and things like that, and just [to] have that realtime position data. It makes us very nervous when we don't hear from teams in quite a while and don't know exactly where they are. So there's a strong safety argument for this kind of technology as well." – P8*

SAR managers mentioned that the heightened awareness of field teams' surroundings, their activities, and their progresses provided by the camera footage can provide Command with additional comfort, confidence, and trust in their field teams.

> *"It would be nice just to sort of have the body camera, you know, just to sort of peek in and see what they're up to. And I guess I would then pester them less frequently with requests of how things are going and what their ETA was if I could actually see what they're doing." – P6 (when asked about how RescueCASTR might have affected a past incident he was involved in)*

Participants mentioned that this could potentially serve SAR managers in moments when a field team does not update Command on their progress frequently. Participants mentioned that these moments could occur when, for example, the team is preoccupied with activities that require a high degree of attention, such as listening for the lost person or driving an ATV or snowmobile, or activities that require use of one's hands, such as scrambling over steep terrain or operating skis. During such moments, field team members might not be able to stop what they are doing to respond to Command's requests over the radio or via text messaging, or they might be in a situation where stopping to respond is cumbersome or frustrating. For example:

> *"It was the heaviest rain I've probably ever been in. [...] We were soaked, and it was because it was raining so hard that our radios weren't working. [...] As we were heading up, I mean, we were already pretty miserable. And Command kept asking us for our UTM [location] coordinates, which is a real pain to transmit over the radio, especially when your radios barely work. And I mean, we were, like, 100 metres away from Command. So I told them 'I'm 100 metres to your east, like literally'. And they're like 'no, we want to see your location'. So that was a real pain. [...] And we're right in the middle of rescuing this guy..." – P10 (when describing a past incident)*

The visual updates are useful if field teams are not disciplined enough to regularly radio Command, or simply do not have good communication skills.

> *"If their discipline is poor and they're not checking in every half hour like [they're] supposed to, or if they're not giving me, you know, clear messages on the radio, then I become more frustrated. You know, if it's a team that has really excellent radio etiquette, [and they] describe things well [and] radio in with their safety checks every 30 minutes, then I have more trust in that team. But if their discipline is poor with regard to those aspects, then that's where I would really wish I could be having a camera on their on their body and see for myself what they're doing." – P6*

Participants also mentioned that, even when a team appears not to be moving on the map or not making progress, they could see potential in using the body camera to confirm whether they are moving, and if not, why. In such an instance, Command seeing a live image of the actions of the team and the conditions they are experiencing would discourage Command from interrupting the team unnecessarily, while at the same time gaining useful status information.

5.2.2 *Using Camera Footage to Infer a Complete Story*

While having a visual picture of the conditions in the field could provide important details and awareness information to Command, participants were quick to point out that this footage may not tell the whole story about what is happening on the ground.

> *"Command would be convinced, based on what they're seeing in the video, that a certain thing is happening, but they don't have the full picture. They don't have the continuity. That comes up all the time, even with radio comms." – P11*

Even though this is the case, participants found that the combination of data sources provided by RescueCASTR beyond the camera images helped them make deeper inferences about a team's situation. In addition to the body-camera footage, RescueCASTR also provides SAR managers with message threads, field teams' live locations and paths (historical location data), satellite imagery, terrain data, and a map showing trails and landmarks. There were a few instances in the study when participants compared the body-camera footage to this other data on the interface to make an inference about the current state of something in the field.

For example, in Scenario 1, P2 found a section of Team A's path, along a trail in a long flat valley, that appeared to go off the trail. The team's path on the map reflecting their actual path (based on their recorded GPS positions) did not reflect the trail's path on the map for about 200 metres, thus making it appear as though they deviated from their assigned path for about 200 metres. To see what was going on, P2 scanned the past body-camera footage along this area:

```
[Looks at the footage on the exact spot on the map where the team's path appears
     to branch out from the trail path on the map.]
P2: Again, I'm trying to see if there was a crossroad.
[Sees the team's camera footage looking toward the bushes beside the trail.]
P2: Oh, potentially here. So they might be looking at the initial trail here.
[Scans cursor forward along the team's path]
P2: But they continue on the easiest one. So that's something I'm going to ask
    the field team leader afterward. Cause now it's too late.
```

His interpretation from scanning the body-camera footage in this area and comparing it to the trail map and the team's assigned path was that there was a fork in the trail that the team saw, and they were required to take the more difficult path as part of their search assignment, but they purposely decided to take the easier path, thus deviating from their assigned path for a short distance. Though he admitted that he could be wrong and said that he would note it down and ask the field team later, when they return to Command after they complete their assignment.

Participants mentioned that the camera footage could sometimes confirm things that appear in other sources of data. For example, P4 mentioned:

> *"I kind of like [the body-camera footage] because it lets me know other than if I didn't have the map, I wouldn't know how close the water was to that team." – P4*

Participants also mentioned that they could compare the body-camera footage in a location to the satellite imagery and map data from the same area too see how much they match or are 'consistent' with each other, then use that comparison make a 'projection' or 'prediction' about what the conditions would be like in another location:

"Combining those body camera images with the map and I can see that it may be that the trail is quite good where they're at. But it won't be very long [until] the trail is going to deteriorate into, you know, just a single track as it gets to the steeper slopes." – P6

5.2.3 *Footage could Impact Workers' Roles and Responsibilities*

While introducing body cameras to WSAR has the potential to enhance the agency's shared mental model and provide an abundance of information that could be useful for planning and decision making, the new capabilities afforded by such a system setup could also impact WSAR workers' traditional roles and responsibilities, shifting the burden of responsibility further away from field teams and more toward Command. While the WSAR command post today often suffers from a lack of information, the abundance of information made available to Command by a system like RescueCASTR could easily bring with it an abundance of responsibility.

For instance, SAR managers pointed out that the sheer amount of information provided in the camera footage, especially when combined with other information such as GPS location and GPS history, could encourage micromanagement on the part of Command. The way teamwork is structured in WSAR today, the field teams are generally trusted to perform their search assignments correctly and without error. Their work is largely decoupled from that of Command.

"In theory the SAR teams in the field are the eyes and the ears of Command." – P1

However, SAR managers pointed out that when Command starts being able to see things from the perspective of the field teams through the body-camera footage, there could come with that an increased desire to take action based on the abundance of information. Participants mentioned that if a SAR manager is not properly trained to trust their field teams, they could be tempted to make judgements for field teams and ask them to change their behaviours prematurely or unnecessarily based on the narrow-window view they have into the field team leader's perspective.

> *"You're kind of looking at the [interface] and [thinking] 'Oh did they see that? Did they see that? Did they see that?' And [...] there's three people on a team or four people on team: 'Yeah, we've got [...] four sets of eyeballs!'" – P1*

This information could encourage some SAR managers to steer away from their traditional role of being the overseer, and overreach into the bounds of the field teams' roles, making the work more coupled. This could be detrimental to field teams if they suddenly have to respond to more of Command's requests.

> *"There's some search managers that I know, I would never let them have this kind of thing because they'd be pestering [the teams]." – P4*

> *"I mean, to a certain point, like, you want to allow the independence of your team. And [...] like the body camera could allow [the] search manager to really micromanage their teams in the field. And sometimes you kind of just have to, like, trust that you train those people and they can make the right operational decisions, and they're going to have more information than just a little body camera." – P7*

While the extra information could increase the desire to take action, it also has the potential to reduce Command's responsibility and desire to check in with field teams via direct radio or text-message requests.

"It takes a lot of pressure off the team leader. It almost offloads, I mean potentially, it could offload responsibility to the search manager. Which I mean they're already pretty busy. But a lot of [...] why they're busy is because they're trying to get information and in a roundabout kind of way, right? So maybe this could offload some of that responsibility and, you know, make it easier for the search manager. Because you know, they don't need to ask for information as much, and they can direct their attention to where it's needed." – P10

This points to an interesting tension: on the one hand, while extra information can certainly be beneficial to Command, especially considering that the WSAR command post today often suffers from a lack of information from the field, *too much* information can easily become distracting, introduce too much responsibility, and fundamentally shift the roles and duties of Command. Some of the participants suggested that they might assign a member of the Command team to specifically play the role of attending to and analyzing the incoming camera-footage data. With current work practices, SAR managers typically assign one or two workers at Command to operate the radio, communicate with field teams, and manually log all communications to and from the field teams. A new system like RescueCASTR could similarly result in having a member of the Command team specifically assigned to operate it and deal with the incoming data it provides.

5.2.4 *Use of Past Data*

Given unpredictable radio and cellular coverage in wilderness areas, it cannot be guaranteed that Command will have contact with field teams at all times, and in fact some WSAR agencies have almost no stable contact with their teams most of the time in their area of jurisdiction. Unless and until connectivity issues become addressed, this will continue to be the case even when teams are deployed with new technologies such as body cameras. However, as several participants pointed out, body-camera footage can still provide utility even when it is not coming in live, but rather being used asynchronously.

> *"One of the challenges we often have in Command is, we send people out to a map coordinate based on what it looks like on a satellite view. But getting that sense of what it really looks like on the ground would be very valuable. Even after the teams come back, it would still have value when we're planning the next round of assignments." – P8*

> *"I would [have had] a lot more comfort in Command [with body-camera footage], having more appreciation for what the terrain is like where my quadders [ATV drivers] were at. Because I haven't, I've never been to that location. I have no idea what it looks like. Other than what I can see on the map and satellite imagery." – P6 (when asked about how RescueCASTR might have affected a past incident he was involved in)*

Asynchronous use of camera footage can happen either when the team is still deployed in the field (in this case, some of the cached past footage could come in during moments when the team regains some contact with Command), or long after they have returned to Command (at which case any of the footage that Command is missing could then be uploaded to Command's interface). There are several use cases for which use of past data could serve utility.

Reviewing past data while a team is deployed. Participants pointed out that if the connection is stable and Command has access to at least some of a team's past camera footage while they are still deployed, they can make use of it while the team is still out in the field, and even communicate with the team while discussing the footage. For example, Command and the field team might need to discuss discrepancies between the information Command has and what the team is experiencing in the field.

> *"If I could use [the body-camera footage], you know, if I talked to the field team leader and said 'okay, why are you off track here', and he shows me 'this is what your mapping system says, but this is the trail, the actual trail'. So my map was wrong, he was right. That [would be] awesome." – P2*

In such an instance, participants mentioned that the field team could direct Command to a specific location that they passed and a specific place in the camera footage for them to view. In a sense, by sending messages or radioing Command, they are already providing Command with some pointers on where to look in the footage.

> *"I don't think anyone's going to review all of the footage of Team D, all like, from start to finish. [...] But being able to have the team flag when there's something worth looking at [...] I think would fix that challenge." – P8*

These kinds of pointers from field teams could help Command narrow their focus in the abundance of information contained in past body-camera footage.

> *"We've mentioned a couple times the idea of bringing in body-cams into SAR and the pushback has usually been 'well you're going to get hundreds of hours of data and [...] no one's going to sit there and go through it all'. And yeah, there's gonna be a lot of data that you just don't really want. But with the teams sort of flagging where they find clues and things like that, that's going to narrow down where you're interested in seeing." – P8*

In Scenario 1, several participants used the messages sent by the teams to narrow their focus when inspecting the past body-camera footage. For instance, P8 heavily inspected the footage from Team B, particularly around a location where they sent a message containing a photo of a clue that was relevant to the lost person in the scenario. He also spent time looking at Team C's footage because they had been moving in the wrong direction, away from their assigned path of travel. However, he did not spend much time scanning the footage of Teams A or D, because they were moving along at a normal pace, along their assigned path, and did not send Command any messages.

> *"[Team] D just sort of chugged along, I wasn't too worried about D. They were kind of doing their thing as was A. [Teams] C and B were really where I ended up spending a lot of my attention, but I knew I had to spend attention there because of the real time data, which was nice." – P8*

Reviewing past data when a team returns to Command. With current WSAR work procedures, when a team returns to Command, they perform a debriefing, during which time the team gives a SAR manager a summary of what they did in the field, what they found, and what, if any, issues occurred. Several SAR managers in this study pointed out that reviewing camera footage could be useful as part of this debrief. For instance, it could be useful for a field team leader to guide the SAR manager through the footage and point out noteworthy things in it, as the team is the one that experiences the conditions in the field firsthand, and they have a better idea of what is 'noteworthy' to show Command.

> *"When they're debriefing, they're supposed to, after the fact, let Command know of issues encountered, hazards, terrain, and all that stuff. But if having a picture makes it a lot easier for them to do it, [then] they can say 'okay, refer to footage around this time'." – P3*

This could help save time and effort on the part of field workers, especially if they need to show things that are difficult to describe in words. Given, that Command may not necessarily be paying attention to the live footage at all times, this 'recap' of a field team's search assignment could help bring Command up to speed if, for example, they missed something important in the footage when it was coming in live. It could also, however, put some burden of responsibility on the field team leader to mark noteworthy spots on the map while they are deployed, or to remember them and point them out when they debrief with Command.

Using past data during role changeovers. Some participants mentioned that the body-camera footage could be useful during role changeovers, when the SAR manager and others at Command are stepping off duty and others are coming in to take their place.

> *"If the next search manager comes in within two days. I'm back here and I can actually access the other professional peers before me. That would be huge. Five years ago, 10 years ago, [...] we didn't necessarily have the information from other GPS tracks and stuff like that. Now we do and it's very difficult to make good decisions if we don't have what happened before." – P2*

Reviewing past data after an incident. Lastly, participants mentioned that it could be useful to review camera footage after an incident, for training and learning purposes, to review what went right, what did not go as well, what (if any) hazards were in the field, and what the organization could do to improve its performance in future WSAR responses.

> *"If something went wrong with a particular team, you'd be able to... you know what happened or, you know what things went well, what things were bad." – P4*

This would especially be useful for agencies based in smaller towns or more remote areas, that do not get called out as frequently. For these agencies in particular, members' skills could easily deteriorate over time if they are not deployed frequently, and so it could be useful to have tools available to look back at previous incidents and relearn from them. While WSAR agencies already conduct a lot of record keeping of the incidents they take part in, which they may make use of occasionally for review purposes, having the opportunity to look through camera footage more carefully and in greater detail after an incident could be beneficial for doing detailed training reviews.

5.2.5 *Privacy, Pragmatic, and Usability Concerns*

Similar to previous work on introducing video to emergency situations (e.g., [77, 84, 100]), participants said introducing body cameras to WSAR could raise privacy concerns, such as the potential to record unconsenting bystanders and the problem of having the live camera footage visible to everyone in the command post at all times, which could be especially problematic in the case that a field team comes across a disturbing scene. Participants also suggested that WSAR workers should have flexibility in choosing when to stream the video, when to record it, and what to present in it.

Participants also reported more pragmatic concerns with using systems like Rescue-CASTR. This included potential challenges with having to store large volumes of video data. Interestingly, while there exists a potential issue around liability and accountability if a WSAR worker does not do something properly and it is captured on video, none of my participants reported such concerns.

5.3 Discussion and Recommendations

I now discuss my findings and their implications for how photo and video streaming could impact WSAR remote collaboration. I also discuss design recommendations and opportunities for such a system, as well as recommendations for its usage by WSAR teams.

5.3.1 *Depth of Multiple Information Sources*

RescueCASTR brings together information from multiple data channels on a single interface. They all present information at various scopes and varying degrees of breadth, depth, freshness, trust, and intentionality. This is also the case in a real WSAR operation using today's technologies, as WSAR command workers have to work with multiple channels of information. In line with the theory of distributed cognition [49], Command's knowledge of the incident response is transmitted through and contained within these data sources. RescueCASTR serves as a means of bringing together these data sources, making it easier for Command workers to view this information in 'focus plus context' [4], while also introducing another data source (body-camera footage) that sits somewhere in between focus and context and is meant to help Command see more from the perspective of field workers. My explorations revealed that participants interacted with these data sources in different ways and had varying impressions of them.

Figure 20 summarizes the information sources that were aggregated in the Rescue-CASTR interface. These fall into three categories, from left to right on Figure 20. First, there were the *intentional/explicit* communications (Figure 20, left), or the messages sent between field teams and Command. Second, there were the *consequential/implicit* com-

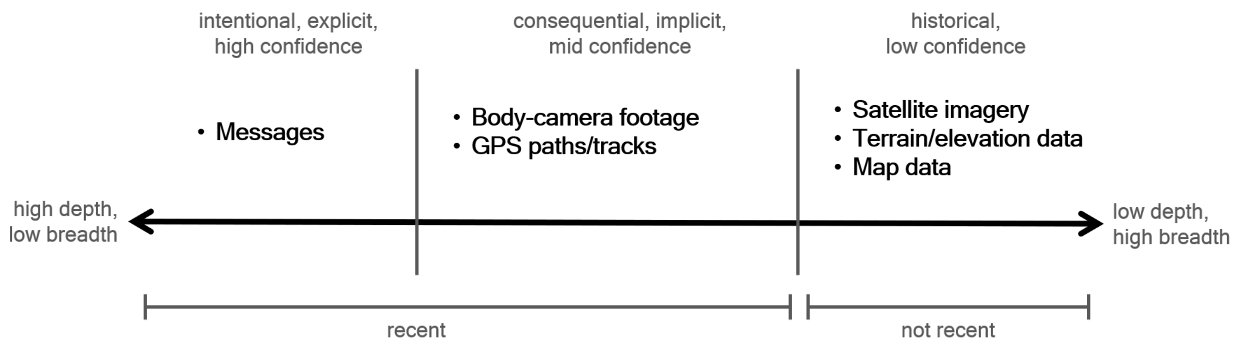

Figure 20: The different sources of information presented to users in the RescueCASTR interface.

munications (Figure 20, middle), or the implicit information that was streaming in as a consequence of teams' actions, such as the body-camera footage and GPS tracks. Finally, there was *historical* information (Figure 20, right), which was information that was already there before the incident began –— e.g., existing trail maps, satellite imagery, and terrain data. These categories also vary in the amount of information depth and breadth they provide. For example, the intentional/explicit communications carry a high amount of depth. They contain the highest amount of detail, though the information is more narrowed and focused on a specific event or finding in a particular location or at a specific point in time. For example, a message containing a clue photograph plus a description of the clue carries a lot of detail, but is focused on only one small part of the higher-level story. The consequential communications on the other hand, carry more breadth about the geographic area across the wider timespan of the search operation, as this information is collected automatically across time. On the other hand, they do not carry as much detail as the explicit messages. For example, the body-camera footage provided a high-level view of what teams were up to and what their surroundings were, but these shots often did not provide much detail and were at times blurry. Finally, the historical information covered the whole search area, but the information was not always up to date and did not present much close-up detail.

From the findings, I also noticed a relationship between the category and depth of the data source and participants' confidence in the information contained within it. I noticed that participants tended to have greater confidence in the data sources that provided more depth (i.e., closer to the left side of Figure 20). My participants mentioned that they had more confidence in the explicit messages that were coming to them directly from field teams, and they generally trusted teams' interpretations of events, findings, and conditions in the field, as they experience these things first-hand. However, participants did not have as much confidence in the body-camera footage, as they said it was sometimes unreliable, distracting, or did not tell the full story. Finally, participants reflected that the historical information (maps, satellite imagery, etc.) might not always be up to date or reflective of the current conditions in the field.

This was also reflected in my participants' actions. For example, participants tended to start with information sources that were of high breadth (i.e., to the right of Figure 20), and gradually work their way toward greater detail (moving toward the left on Figure 20). There were also numerous instances when participants tried to make comparisons and contrasts between these data-source categories to build a more-complete picture and tell a more comprehensive story, to get the focus *plus* the context (see [4]). They did this through, for example, looking at the body-camera footage to see what a team was experiencing when they sent a message, or looking at the satellite imagery and terrain elevation data surrounding a body-camera shot to get a sense for how long the terrain will remain the same for a certain team. This illustrates the potential for multiple channels of information with varying breath, depth, and freshness to support sensemaking, situation awareness, and the building of a mental model in the WSAR command post, as long as those information sources ultimately help Command narrow in and focus on the details that matter in the moment, for the specific tasks that the workers in the command post have on hand.

5.3.2 *Facilitating the Narrowing of Focus*

RescueCASTR does a good job of providing implicit communication, thereby reducing the number of explicit information requests. However, it does so at a cost: it gives large amounts of information – much of which may not be important or useful. A next iteration of this tool ought to address this by reducing the visual salience of unimportant information to help Command focus on what is important (i.e., to narrow their focus). This raises the question: can we introduce automation that interprets the video footage and adds a semantic layer for signalling – e.g., on changes in environment, weather, and so on – to help Command focus their attention on these parts of the footage?

A future iteration of RescueCASTR should be designed to suggest to the commander which spots in the footage might be useful to focus more of their attention. For example, my findings suggest that SAR managers are interested in parts of the footage where the circumstances of a team's situation change, or the team does something unpredictable. I noticed that participants wanted to explore footage around locations and points in time where the following types of events occurred:

- A change in the team's environment or surroundings
- A pertinent change in the team's speed or direction of movement
- Moments where the team went off track from their assigned path of travel
- A change in the weather or lighting conditions surrounding the team
- A change in the terrain (e.g., an incline or elevation change)

- A change to the team's activities (e.g., changing from a grid search to a hasty search)
- Instances when the frame contains something of note (e.g., a body of water, a person, an animal, or a clue)
- Instances when the camera is pointed downward (e.g., to indicate looking down at a clue on the map)
- At specific locations, manually selected by either Command or the field team
- Near locations where clues were found
- Near locations where the field team messaged Command

Some of these things can be pointed out manually by Command or field teams. Most of these could also be detected automatically by the system itself, through computer vision, artificial intelligence, or other related technologies.

5.3.3 *Designing for Low-Bandwidth and Network-Sparse Situations*

While I designed RescueCASTR to work in both 'online' and 'offline' conditions, participants pointed out that radio dead zones in the wilderness can actually be more severe than what my scenarios illustrated. If operating in such conditions, body cameras should stream photos less frequently and at lower resolutions, while still trying to provide the 'heartbeat'-like contextual awareness of teams' visual surroundings and activities that participants enjoyed and found benefit from in this study.

The same criteria I outlined above for designing to help Command narrow their focus when figuring out what to review in the footage can also be used by the field team's device to prioritize which images are sent first in a low-bandwidth situation. For example, in a low-bandwidth situation, once a field team regains some contact with Command after being in a radio dead zone for two hours, the system on their end could send sections of the footage where they made a turn, where the surroundings (e.g., vegetation) or weather changed, where they went off track, and where clues were found; as well as their most-recent camera image for a view of their present situation. The system could send lower-resolution versions of these photos, to save bandwidth, and Command could gain access to higher-resolution versions of these later when the team returns to Command. Furthermore, the system could prioritize sending explicit messages (including text, audio, and photo messages) before sending implicit data such as body-camera footage. In this way, Command has access to the most important information first, and can hopefully receive it within the narrow time window that the team has some contact with them.

5.4 SUMMARY

In this chapter, I presented an remote simulation user study to evaluate the RescueCASTR interface. The findings from this study illustrate that WSAR managers see video/picture streaming from wearable cameras as something that could be useful to give them contextual awareness of a field team's progress and status. This awareness could provide additional confidence and comfort, as well as reduce the amount of explicit communication requests (e.g., radio checks) from Command to the field teams, which could help field teams focus more on their in-the-moment duties, as well as save time on Command's part, allowing them to put their focus toward other activities. WSAR managers also pointed out that the camera footage could be useful for planning and reviewing activities, both during and after a response. However, the new capabilities afforded by body-camera streaming could also impact WSAR workers' traditional roles and responsibilities, shifting the burden of responsibility further away from field teams and more toward Command. For example, Command could be encouraged to micromanage the teams, and feel responsible for acting on the knowledge contained in the camera footage, even if they are not watching all the time and even though field teams still have a better view of the situation.

This demonstrates that an interface design like RescueCASTR can provide rich and actionable contextual information about a field team's activities, status, and surroundings, all while requiring little effort from field teams. Body camera footage can be a bridge between the 'focus and context' [4] of other data channels. For example, it can add *context* to radio updates, text messages, and clue photos, while providing more *focused* detail and depth to information sources such as maps and satellite imagery. However, camera streams should not be thought of as a tool to replace more direct (explicit) communications or even as a means of providing super-detailed shots. Rather, the implicit information source should be treated as a tool to augment existing explicit communications to help Command build and expand their understanding of events in the field and help them narrow down what to focus on next.

In the next chapter, I present an overall discussion of my dissertation work, including design implications, reflections on the potential impacts of technologies on WSAR work practices, general contributions to the field of Computer-Supported Cooperative Work (CSCW), and lessons learned from evaluating RescueCASTR via a remote scenario- and simulation-based user study.

6

OVERALL DISCUSSION

In this chapter, I discuss the important lessons and takeaways that I think researchers in Computer-Supported Cooperative Work (CSCW) and Human-Computer Interaction (HCI), as well as technology designers building tools for wilderness search and rescue (WSAR) remote collaboration, should take away from this dissertation work. The lessons are drawn from the findings from the investigative study on WSAR workers (Chapter 3) as well as the findings from the user study evaluating the RescueCASTR system design (Chapter 5). These lessons inform not only the design of technologies for remote and distributed collaboration in WSAR, but also more generally for teams that are geographically distributed, moving across large geographic areas, and collecting and sharing information related to the geographic area. As I provide this discussion, I relate these lessons and design implications to prior literature in CSCW and HCI, while also noting this dissertation work's contribution to theories on teamwork, awareness, and cognition in CSCW. I also reflect on lessons learned from evaluating an interface for emergency response via a remote simulation-based user study.

6.1 Design Lessons

Design Lesson 1: *Design to bridge the perspectives of Command and the field.*

Both of the studies presented in this dissertation highlight the importance and benefit of bridging the perspectives of field teams and Command. To bridge the field and Command perspectives means to allow Command workers to see and understand the situation from the viewpoint of field teams, and to allow field workers to understand the situation from the bigger-picture perspective of Command. Shared awareness of each other's perspectives can lead to shared agreement, and thus a shared mental model.

Study 1 highlighted that Command wants to maintain consistency, shared agreement, and control among the response team's members, including among all members of the Command team as well as across all of the field teams. Command does not want there to be any discrepancies in team members' understandings of what is happening, what field teams are doing, what they should be doing, and what they are finding. Similarly, field teams often want to have greater awareness of what else is happening in the response, beyond just what they are able to observe within their own field team. In addition, they want to have a sense of the bigger picture of the operation, which is one of the reasons why field teams cannot help but to eavesdrop on radio conversations between Command and other field teams.

Maintaining some level of understanding between the two perspectives can help both sides in their work. Study 2 revealed that understanding more about what field teams are experiencing, including the weather and ground conditions they are being deployed in, the distances they are travelling, and the skills and unique traits of their members can help Command better understand their needs, including needs for equipment, food, water, or medicine. Furthermore, the findings from this study also suggest that a better understanding of the conditions and teams' findings in the field from their perspective can help Command better plan future actions in the search response, including upcoming task assignments and decisions about where to send teams next, what equipment to deploy them with, and who to include on each team. Visual and implicit communication and information-sharing channels such as body-camera footage from field teams (as also mentioned in Lesson 2, below) is one way to bring more of the field perspective to Command. Another way could be to simply provide more means for field teams to explicitly communicate visual information; e.g., through a video call. Additionally, aside from contextual awareness, Study 2 also revealed that a system like RescueCASTR could provide commanders additional visual awareness of the field environment itself, which SAR managers could make use of both live and asynchronously. In other words, the body cameras, while intended to provide information about a team's activities, also serve as a means of capturing or 'scanning' the field environment across the teams' paths and over time. In the future, other technologies such as 360° cameras and/or 3D/depth-capture cameras worn by field teams could capture higher-fidelity or 3D imagery of the search environment as the teams complete their assignments. Even if the captured information is not transmitted or used in realtime (e.g., due to low bandwidth), it could still be used asynchronously, after the team returns to the command post, to provide commanders with a higher-fidelity understanding of the conditions in the field. Drones (e.g., [53, 54, 81] could also be used to provide overview shots of the environment or third-person views of field teams in context with their surroundings, thus providing a more clear illustration or narrative of their actions. I recommend the exploration and use of such technologies as future work.

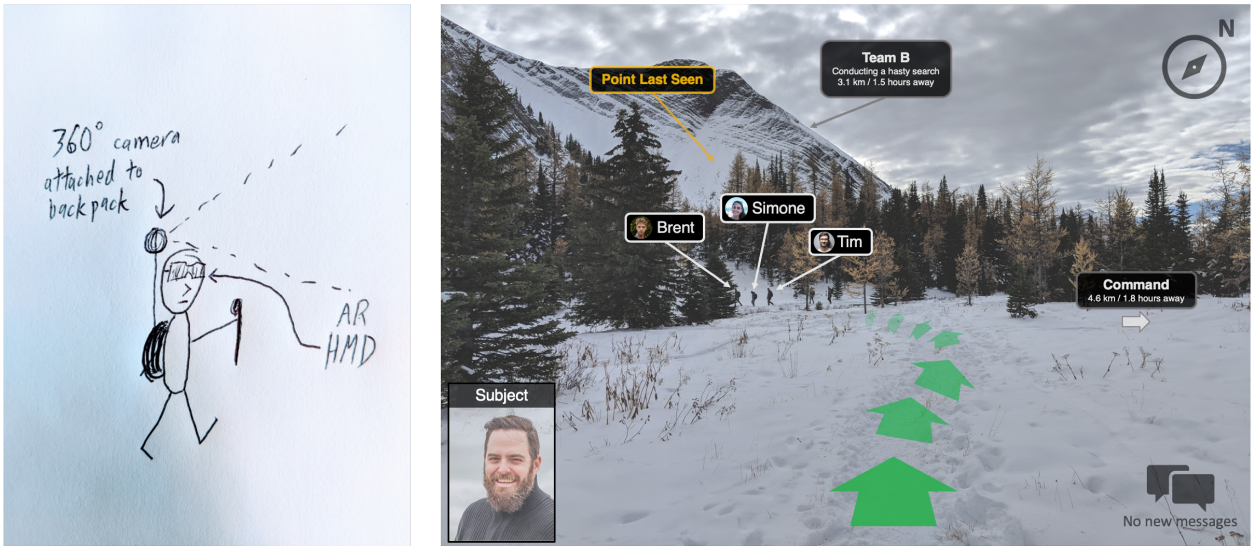

Figure 21: A mockup of an augmented-reality (AR) interface designed to display information about the bigger-picture of the search response to field workers. *Left:* a sketch of the wearable hardware in use, including an AR head-mounted display (HMD) through which the field worker sees important visual information. *Right:* a mockup of the interface that appears through the HMD.

Similarly from the field-team side, participants in Study 1 suggested that having a more thorough understanding of the higher-level picture of the search response from the perspective of Command, as well as of Command's goals and decision-making rationale, could help field teams and team leaders better understand the reasoning for why they are asked to perform their assignments a certain way. Field-worker participants also mentioned that it could help them understand how their own actions contribute to the search response as a whole, thus providing a greater sense of team contribution and fostering a greater sense of community among the response team as a whole. One way to bring this perspective to field teams without distracting them too much from their own activities could be through an augmented-reality (AR) interface that displays higher-level information about the search response (e.g., other field teams' and members' locations, the location of the command post, paths, and locations of clues found by other teams) to the field team in relation to their first-person view and current location in the field (interface mockup in Figure 21).

Design Lesson 2: *Design to enhance non-verbal, implicit, and automatic information sharing.*

In WSAR today, most information sharing between the field and Command happens via explicit communications over the radio and text/photo messaging. However, previous literature has highlighted that implicit communications also play an important role in supporting team cognition [33, 107]. While Command workers are able to communicate implicitly with each other, Study 1 revealed that opportunities for implicit communication between the field and command post are limited. Implicit communication happens as a consequence of one's actions [33], and thus it requires awareness of one's actions. Aside from tracking teams' GPS locations, Command workers are unable to remain aware of teams' actions, except when they explicitly message Command. The consequences of this include Command needing to ask field teams for radio updates on a regular basis in order to get an updated understanding of their situation. Such explicit updates require time and effort from both field teams and Command, often just to report mundane or repetitive information. While some updates are crucial and need to be communicated explicitly (e.g., a team reporting a medical emergency, or finding the lost person), not everything needs to be communicated explicitly or verbally.

Study 2 revealed that when Command has access to more implicit communications from field teams in the form of body-camera images, they are able to remain better aware of their actions, safety situations, and needs without messaging them. This could lead to a reduced need to explicitly message the teams, thus allowing both Command and field teams to focus more on their own duties. Furthermore, as revealed in Study 2, implicit data channels can help bridge the perspectives of field teams and Command (in line with Lesson 1 above), and thus help enhance the organization's shared mental model.

In addition to implicit communications from the field to Command (e.g., through body-camera and location streaming, as provided by RescueCASTR), field teams could potentially benefit from implicit and non-verbal communications from Command to the field. Study 1 revealed that while *feedthrough* and *deictic referencing* [27] from commanders to a field team leader were easy when a field team was at Command (either before or after an assignment), they were non-existent during an assignment, when a team was out in the field. For example, while briefing a team at the command post, SAR managers would make references to specific locations on a map via pointing and annotating, and gesture toward specific locations or directions in the real world. A SAR manager marking the team's copy of a map serves as a form of 'asynchronous deictic referencing' that the field team could refer to at a later time when they are deployed. When a team is deployed though, Command could only synchronously refer to locations on the map explicitly by verbally communicating landmark names (e.g., 'Lake Tang', 'Neustaedter Mountain') or GPS coordinates. Furthermore, they could not make references in relation to the real environment from the perspective of the field teams. It could be beneficial to provide Command with a means to refer to a field team's surrounding environment in realtime via deictic referencing. This could be done through, for example, allowing Command to annotate parts of a field team's body-camera footage, and allowing the team to see those annotations in realtime. Another solution could be to allow Command to pin, annotate, or mark spots on a digital map, and to have those annotations be displayed to the field team in realtime in relation to their perspective of the environment (similar to the world-stabilized annotations on Figure 21, displaying a path and key locations in relation to the field worker's first-person perspective of the environment). Similar design solutions have been implemented and explored in previous work (e.g., [103]).

Design Lesson 3: *Design to balance the burden of responsibility between Command and field teams.*

Designers need to consider WSAR workers' roles and responsibilities, as well as how new technologies could impact their traditional roles and responsibilities. The findings from Study 2 suggest that while the abundance of information provided by additional implicit data channels such as body cameras could reduce the responsibility for field teams to check in with Command and give them status updates, by having status information flow into Command automatically, it could also shift responsibility toward Command. Current work protocols result in WSAR being a largely de-coupled collaborative activity, at least during the search phase. However, the introduction of a new visual channel, bridging the perspectives of Command and the field, may tend to make the work more coupled. This could be beneficial during instances where Command can be a 'good partner' to field teams, or where they could make use of more information from the field for their own planning duties (e.g., understanding how easy or hard it is to deploy resources to a certain area), without having to burden field teams to collect that information. However, this could be detrimental when the new information is not sufficient for the task at hand (e.g., it does not tell the full story), or the field team has a better perspective (and thus can make a better judgement).

Designers should consider ways to reduce the information burden on SAR managers and allow them to focus more of their attention on the pieces of information that are important. As mentioned in Chapter 5, some of this could be done through automation that interprets the data (e.g., the camera footage) coming in from field teams and determines specific foci of interest for Command to focus on (e.g., a change in environmental or terrain conditions, change in weather, an object of interest appearing in the camera view, or other key events) within the abundance of information. Furthermore, while field workers may not need to give radio updates to Command as frequently, they perhaps could be responsible for helping Command narrow their focus in the body-camera footage, both while they are in the field (by 'pinning' noteworthy locations that they want Command to take a look at) and after they return, during the debrief phase. SAR managers could also consider assigning one or two people on the Command team to attend to managing the RescueCASTR Command interface, similar to how one or two workers are typically assigned to manage the radio.

Design Lesson 4: *Design to allow Commanders to triangulate focus plus context from multiple information sources of varying depth and breadth.*

There are opportunities to collect vast swaths of information from the field automatically, even if that information does not provide much depth. Given that field teams must remain focused on searching for the lost person, there is a limit to how much information they can explicitly communicate to Command. However, technologies such as cameras and GPS devices can record and/or broadcast a continuous stream of data from the field automatically, without much direct intervention from users.

The findings from Study 2 illustrate the potential benefits of making use of multiple information sources, some explicit and others implicit, and with varying degrees of depth and breadth, to support team cognition and awareness. Commanders ultimately want to work with a high level of detail, and they put a high degree of trust and confidence in their trained workers on the ground, more so than the information streaming in as a consequence of field teams' actions (e.g., the body-camera footage and the GPS tracks). However, the findings show that it could be beneficial to start off with a high level of breadth and use that to gradually work down and obtain the details necessary to make important decisions. While implicit and automatic information streams can provide wider temporal and spatial coverage of the incident response, there is a tradeoff in that the information contained may not be fully trusted or provide a conclusive story. Rather, the information was seen by participants as something that could provide Command workers with hints about where to direct their attention next. While the lower-level details should ultimately come directly from the workers on the ground through explicit communications, it could be helpful to provide more opportunities to obtain breadth first through consequential and implicit information channels, so that Command does not need to make frequent use of explicit communications to obtain mundane information such as a team's location or a view of their surroundings. This in turn could also help field teams focus more on their duties.

Similar findings have been observed in prior literature, in that presenting the 'focus plus context' of a data source or activity can help users better understand it [4, 5, 65]. I argue that multiple data sources, providing layers of breadth and depth, can allow WSAR Command workers to understand the current status of the operation from multiple scales and perspectives. While each data source might not tell a full story, they could each play a role in helping Command build a mental model of the situation. For example, body-camera footage could provide context to field teams' radio messages, allowing them to describe fewer details in words while Command puts the two data sources side-by-side to get a more solid understanding of the situation. Another example: if something looks unusual in a team's GPS path or body-camera footage, Command could message the team directly and ask them about the anomaly in order to clear up the confusion. This would allow Command to use explicit communications to seek more details to complement something they saw in an implicit data stream. To support this, in addition to Command's RescueCASTR interface, it would be beneficial to design an add-on interface for field teams that allows a field team leader to view their own GPS path and body-camera footage history, so they can understand what information Command is receiving about their actions. Furthermore, such an interface could connect to Command's interface, allowing both the Command and field users to refer to and discuss specific parts of the camera footage and GPS tracks. For example, if Command has a question about what a team was doing at a particular location on the map, Command could highlight that location or refer to a specific section on the team's path, and the team leader would see where on the map Command is referring to on their device.

Study 2 confirmed previous work in CSCW that suggests that complete shared mental models are not always necessary in collaborative work [15, 95], and that the resulting information can sometimes lead to information overload or distraction. I extend this by arguing that, rather than aiming to provide commanders with complete details about all of the field teams' knowledge and experiences, designers should instead aim to provide useful *context* to the details they *can* provide. Furthermore, much of this context can be obtained automatically, or implicitly, as a consequence of field teams' activities.

Design Lesson 5: *Design to aggregate information geospatially and temporally.*

Study 1 highlighted the importance of aggregating communication and information channels together into one place and presenting it in a simplified way. Previous literature has highlighted the value of using maps as a tool for communication, coordination, and sensemaking in SAR [1]. Furthermore, understanding team members' actions and contributions to a task in relation to the spatial and temporal bounds of the workspace is important for maintaining workspace awareness [45]. Therefore, I argue that it is beneficial for WSAR remote-collaboration interfaces to display information geospatially, in relation to a map of the search area, and temporally, in relation to the timespan of the search response, in order to allow team members to understand where the information fits within the spatial and temporal bounds of the response. For the command post, one way of doing this is to display the information on a map and timeline, as RescueCASTR does. Participants from Study 2 found this method of presentation to be useful, though they did mention that sometimes the map became too cluttered. One way to address this could be to allow users to temporarily hide irrelevant information on the map (e.g., by unchecking it on a checkbox). Other participants mentioned that it would be beneficial to rewind/fast-forward through or replay data playback on the map via scrubbing through the timeline, similar to playing back a video (e.g., selecting a point on the timeline only reveals on the map the information that was available or sent at that moment in time).

6.2 Implications for the design of remote collaboration technologies for other command-and-control activities

This research has revealed the value of implicit communication channels, automatic data collection/aggregation (in the spirit of enhancing distributed cognition), and bridging perspectives in activities involving command and control of several field teams scattered and moving around a large environment. While I conducted this research within the specific context of WSAR, these interventions could also provide value to (and inform the design of technologies for) other collaborative command-and-control situations involving a similar number of sub-teams or individuals moving around a large space. Such situations include other emergency domains such as police work, firefighting (including building and wilderness firefighting), and disaster response. Indeed, police officers in many parts of the world already use body cameras, though mainly for archival and evidence purposes [77]. In firefighting, while the environment might not be as large as a wilderness area, firefighters might benefit not only from seeing live footage from their members in different parts of a burning building, but also from reviewing past footage in certain key locations – e.g., reviewing layers of past footage from a single room in the building to get a sense of how the fire has grown in there. In disaster response, there have been many explorations of the use of information from multiple sources (e.g., from social media [104, 105, 111]) in supporting situation awareness and shared mental models.

With that said though, introducing additional implicit information streams also comes with a cost. For example, it could introduce the potential for information overload and the need to balance workload and adjust team members' responsibilities based on the new information channels being provided. Furthermore, implicit and automatic information channels would likely become more beneficial as the number of collaborators and sub-teams increases (e.g., in the case of large-scale disaster response [104, 105, 111]). Conversely, in situations involving fewer collaborators, commanders could likely more easily afford to rely on explicit communications if it is proven too difficult to incorporate new implicit modalities into their workflow. For example, in a rescue-only operation involving only a single team deployed to a single location, explicitly messaging a single team and logging their communications over time would not require as much effort as, say, doing the same for a larger number of teams over a longer period of time. Thus, the specific context and scale of the activity (i.e., the number of collaborators or sub-teams, the size of the workspace, and the time span of the activity), as well as the level of urgency need to be taken into account when deciding whether or not it would be beneficial to introduce new information-sharing modalities into an organization's workflow, as well as how many new modalities or interventions to introduce.

Lastly, some minimal interventions could likely be introduced without too much impact to an organization's workflow. For example, introducing a system or mechanism that allows incoming radio messages from field teams to be automatically transcribed and recorded (with timestamps and GPS locations) to a database, where they could then be displayed in chronological order, on a timeline, or on a map in relation to other available data on the response, and where they could also be triangulated with the other data to infer focus plus context, could provide notable value to a Command team. Such an intervention could allow them to more easily access, comprehend, and process the data as part of their collective knowledge, thus enhancing distributed cognition and team cognition, while at the same time requiring few technical or infrastructure requirements or adjustments to the organization's existing work practices. Thus, rather than going all in on introducing numerous new technologies or modalities, an in-between approach of introducing some new technologies or minimal interventions could be more beneficial in some contexts.

6.3 Lessons learned from evaluating an interface for emergency response via a remote simulation-based user study

Initially when implementing RescueCASTR, I planned for it to be a fully-functional high-fidelity prototype, running with incoming photo or video streams from body cameras worn by outdoor mobile users. However, a couple of months into the implementation of the prototype (by March 2020), the COVID-19 pandemic resulted in the closure of research facilities and restrictions on in-person studies in Canada. I foresaw these restrictions staying in place for at least several more months, and potentially longer, and thus decided to plan for the possibility of not being able to run an in-person user study to evaluate the RescueCASTR interface. I thus shifted gears from implementing a high-fidelity prototype of RescueCASTR and running an in-person user study with WSAR workers, to implementing a medium-fidelity prototype of the interface for Command that plays back pre-recorded use-case scenarios, and running a simulation-based remote user study with WSAR managers. Through this process, I learned some valuable lessons about this study method that I would like to highlight to readers, as they could be useful for evaluating other user experiences via remote and simulation-based user studies, and especially interfaces designed for specialized user groups and contexts.

The Chapter 5 study to evaluate RescueCASTR was based on use-case scenarios. Participants, who were already WSAR managers and who also had experience as field workers, were asked to roleplay and imagine they were a WSAR manager in the command post, responding to an incident and managing a set of teams deployed in the field. **Scenario- and roleplay-based evaluation techniques can be beneficial for evaluating a new user interface** [99]. Grounding users within a scenario or role helps them use and reflect on the interface based on its intended context of use. While there are challenges and limitations to this approach, such as on ensuring ecological validity, such challenges can be minimized.

To minimize impacts on ecological validity, **I recommend that researchers running scenario-based studies base their scenarios on real-world incidents experienced by the target user group**. For my work, it helped that I had already interviewed several WSAR workers in Study 1 and asked them to recall real incidents that they were a part of, and that I had also observed some of these on my own through both the mock-search activity from Study 1 and other training activities I informally observed while establishing relationships with WSAR workers and agencies in the early stages of my dissertation research. In WSAR and many other specialized domains, there may be recollections of such incidents in news articles; though it is usually more valuable to get a recollection from the first-person perspective of a real worker, or an observation from a fly-on-the-wall perspective.

I also recommend using scenarios that are both useful for answering one's research questions and ecologically valid. In order to construct such scenarios, I recommend that researchers think about what kinds of tasks or higher-level goals they want to see users try to achieve with their interface, and try to recall sample real-world incidents where workers tried to achieve similar goals. Following this, the next step should be to construct one or more scenarios, in a manner similar to the real-world stories one has collected from domain experts, that lead users to try accomplishing those goals. The researcher would have to decide whether to make the scenarios more linear, with little freedom of choice (similar to a task-centred walkthrough [72]), or more interactive, with high freedom of choice and exploration (similar to a video game). The benefit of the first approach is that it results in a more-structured scenario, where participants complete all of the lower-level tasks in the preferred order, while the benefit of the second approach is that it results in a more realistic scenario, where the user has the freedom to explore various possibilities, thus possibly revealing insights not only on the lower-level design choices in the interface, but also on the higher-level thought patterns of the users. The approach I took in Study 2 fell in between those two approaches – I gave participants a higher-level overview of what the current status of the activity was and what goals they were supposed to accomplish (thus giving them some constraints), while having them strive toward those goals in whichever fashion and order they pleased (thus giving them some freedom).

Once such scenarios are constructed, **I recommend seeking feedback on them from domain experts in the target user group, specifically on their realism**. I took this approach in designing the scenarios for Study 2, by sending them to WSAR managers then iterating on the scenarios based on their feedback.

While evaluating the system design via the scenarios, it can be beneficial to employ a think-aloud process [71, 86, 87], especially if the user is acting alone and not speaking with other users in the activity. Doing so can help researchers understand not only what actions the user is performing, but also why the user is performing these actions the way they are. Think-aloud studies help researchers understand users' thought and decision-making processes.

Finally, **once the user has completed the activities from the scenarios, I recommend interviewing them specifically to gauge their thoughts about how they might imagine or speculate the interface being used in their actual work, in a real incident**. This is the approach I took in Study 2. I specifically asked participants to recall an incident they were a part of in the past in which it was challenging to remain aware of teams' activities and statuses, and to try imagining how that situation might play out of they had a fully-functional version of the RescueCASTR interface running in the command post during that incident.

Remote user studies can allow a researcher to reach out to a larger number of domain experts that might not be easily available in one's local area. In addition, simulated user studies can allow a researcher to evaluate a design through a low-cost means before refining it further and testing it in the real world. With that said, simulated user studies do suffer from a lack of ecological validity, as the situations do not perfectly replicate the environments that users are used to working in. Though such studies can still provide useful insights, one does need to reflect on the limitations on ecological validity. For example, while the study on RescueCASTR revealed important insights on how multiple information channels can provide layers of focus plus context, how WSAR managers perceive and make use of such channels in different ways, and how introducing additional implicit information sharing could impact WSAR collaborative practices, we are still left with a lack of understanding of how the stressful environment and the nuances of collaboration with field teams and other members of Command affects WSAR managers' use of a system like RescueCASTR in the real world, and what that implies for how such a system should be designed. Such insights could be revealed by future work, through in-the-wild training activities with WSAR workers, and perhaps with a more-refined version of RescueCASTR, iterated on based on the findings from the initial study.

6.4 SUMMARY

In this chapter, I highlighted a set of design lessons and implications for building technologies to support remote collaboration in WSAR and other activities involving remote collaboration across multiple teams or endpoints moving around a large geographic environment. These lessons were drawn from the findings from both of the studies presented in this dissertation:

- **Design Lesson 1:** Design to bridge the perspectives of Command and the field.
- **Design Lesson 2:** Design to enhance non-verbal, implicit, and automatic information sharing.
- **Design Lesson 3:** Design to balance the burden of responsibility between Command and field teams.
- **Design Lesson 4:** Design to allow Commanders to triangulate focus plus context from multiple information sources of varying depth and breadth.

- **Design Lesson 5:** Design to aggregate information geospatially and temporally.

Furthermore, I highlighted a set of lessons for evaluating new interfaces for emergency-response and other serious activities via remote simulation-based user studies:

- **Method Lesson 1:** Scenario- and roleplay-based evaluation techniques can be beneficial for evaluating a new user interface.
- **Method Lesson 2:** Base study scenarios on real-world incidents experienced by the target user group.
- **Method Lesson 3:** Use scenarios that are both useful for answering the research questions and ecologically valid.
- **Method Lesson 4:** Seek feedback on study scenarios from domain experts in the target user group, specifically on their realism.
- **Method Lesson 5:** Consider employing a think-aloud process, especially if participants are working alone and not communicating/interacting with other participants.
- **Method Lesson 6:** Interview participants to gauge their thoughts about how they might imagine or speculate the interface being used in their actual work.

In the next chapter, I conclude this dissertation, provide a summary of its contributions, and outline its limitations and possible avenues for future research in this space.

7

CONCLUSION

The goal of this dissertation was to advance understanding of how to design and build technologies to better support remote collaboration in wilderness search and rescue (WSAR). The underpinning research problem addressed by this dissertation was that *"we do not know how technologies should be designed to support rich forms of remote communication and information sharing between the Command team and field teams in WSAR."* In addressing this research problem, I addressed the following sub-problems:

- **Research Problem 1:** We have a limited understanding of the challenges that WSAR workers face in remote communication and distributed collaboration.
- **Research Problem 2:** We have a limited understanding of how distributed collaboration technologies should be designed to better support building and maintaining a shared mental model in WSAR.
- **Research Problem 3:** We have a limited understanding of how new remote collaboration technologies could impact WSAR work practices, including how WSAR workers collaborate and maintain a shared mental model across distances.

7.1 REVISITING DISSERTATION GOALS

In this section, I review the progress this dissertation work made in addressing the research problems outlined above.

Research Problem 1: *We have a limited understanding of the challenges that WSAR workers face in remote communication and distributed collaboration.*

To address this research problem, I ran an investigative study with WSAR workers in Western Canada. This study, presented in Chapter 3 and published in [55] and [56], involved two phases. For the first phase, I interviewed 13 WSAR workers, including four SAR managers and five field team leaders, in order to better understand WSAR remote-collaboration practices and challenges from both the field and Command perspectives. For the second phase, to complement this understanding through a fly-on-the-wall observation perspective, I observed a day-long mock WSAR search response from the command post. The findings from this study provided insights into how commanders and field teams communicate, collaborate, and share information when scattered across distances and throughout the duration of a response.

I found that WSAR workers face challenges in maintaining a shared mental model, particularly when working across large geographic distances (i.e., between the command post and the field teams). WSAR workers primarily use two-way radios, cell phones, and satellite phones to communicate remotely when scattered across distances. While there are numerous opportunities for members of the Command team to communicate non-verbally and understand each other's actions and intentions through implicit communication, feedthrough, and deictic referencing (and the same is true for members of each individual field team), such communication is lacking between Command and the field teams, as they work mainly across distances. Furthermore, I found that workers communicate remotely to achieve various goals and to communicate information with varying levels of urgency. This warrants the use of multiple communication modalities and information streams. However, bringing in additional communication modalities increases the risk of information overload, and thus WSAR workers today still rely mainly on communicating remotely via radio and text messaging.

This study demonstrates opportunities to provide implicit communication and awareness remotely, help teams maintain a shared mental model even when synchronous realtime communication is sparse, and bring together multiple streams of information and communication while making sure that they are presented in ways that aid WSAR workers rather than overwhelming them.

Research Problem 2: *We have a limited understanding of how remote collaboration technologies should be designed to better support building and maintaining a shared mental model in WSAR.*

To address this research problem, I applied the findings from the investigative study to generate a set of design opportunities and recommendations (presented at the end of Chapter 3) for technologies to help WSAR Command workers and field teams more effectively communicate and share information with each other remotely. They include the following design opportunities (DOs):

- **[DO1]** Technology can be designed to help bridge the perspectives of the field team and Command through implicit and automatic information sharing.
- **[DO2]** WSAR workers could benefit from additional remote-communication modalities and information channels beyond just audio and text.

- **[DO3]** WSAR workers could benefit from additional opportunities for asynchronous communication and information sharing.

As well as the following design recommendations (DRs):

- **[DR1]** Anticipate network sparseness, and design communication modalities and information channels that take these into account.
- **[DR2]** New technologies should not burden or distract workers.
- **[DR3]** Communication modalities and information channels should be aggregated, to allow for easy viewing, searching, sorting, and comparisons.

From these opportunities and recommendations, I designed and evaluated a prototype of a system for the WSAR command post, called called ***RescueCASTR***, or *Search and* ***Rescue C****ontextual* ***A****wareness* ***Str****eaming Platform*. This interface is designed to help WSAR Command workers build and maintain awareness of field teams and their activities. RescueCASTR aggregates information from multiple data sources and communication channels into a single interface, presenting that information geospatially (in relation to a map of the search area) and temporally (in relation to a timeline of the WSAR response). It also aims to provide commanders with heightened contextual awareness of field teams' statuses, surroundings, and activities through the displaying and logging of body-camera footage, GPS locations, and messages. This interface is designed to not provide too much of a burden on field workers (as the body cameras stream photos passively without user intervention), as well as to provide use while teams are on- and off-line.

Research Problem 3: *We have a limited understanding of how new remote collaboration technologies could impact WSAR work practices, including how WSAR workers collaborate and maintain a shared mental model across distances.*

To address this research problem, I evaluated RescueCASTR through a remote user study with WSAR workers across Canada, to understand the opportunities that such a system could provide to WSAR commanders, including the potential for WSAR managers to use the system as part of their workflow in building and maintaining a mental model of the operation, as well as in projecting ahead and planning future decisions. Through this study, I uncovered insights into how new technologies could impact WSAR collaborative practices, particularly around remote collaboration. I found that WSAR managers see video/photo streaming from wearable cameras as something that could be useful for providing contextual awareness of a team's progress and status, essentially acting as a bridge between the 'focus plus context' [4] of other data channels. The awareness provided by the body-camera footage could give additional confidence and comfort to Command, as well as reduce the need for explicit communications with field teams. However, it could also impact WSAR workers' existing roles and responsibilities, shifting the burden of responsibility away from field teams and more toward Command. This demonstrates that, while wearable-camera footage could be beneficial to Command, they need to have the tools and means to narrow their focus within the abundance of information provided. Furthermore, camera streams should not be thought of as a replacement for more direct communications, but rather as another tool available to help Command supplement their understanding of events in the field and help them narrow their focus.

7.2 Revisiting Contributions

In this section, I revisit the contributions of this dissertation work, which I outlined in Chapter 1. To summarize, this dissertation makes the following contributions:

Contribution 1: *An understanding, through the lens of Computer-Supported Cooperative Work (CSCW) theory, of how WSAR workers use technology to collaborate and share information remotely during a search response, and the challenges they face in doing so.*

In Chapter 2, I provided an overview of current CSCW theories on teamwork, cognition, awareness, and mental models, and related it to what we already know about WSAR work practices. In Chapter 3, I presented a study that provides further understanding of how WSAR teams use technology and work practices to collaborate and share information across distances, as well as of how they use technologies and artifacts to store information and make use of it asynchronously, across time, throughout the search response. The findings from this study provided important insights that help us understand the communicative and information-sharing needs and challenges of WSAR teams, including the need to maintain a shared mental model, the challenge of a lack of implicit information sharing between the field and Command, and the difficulties of a lack of consistent radio connectivity leading to reduced opportunities for synchronous communication.

Contribution 2: *Insight on how technology can be designed to better support WSAR remote collaboration.*

Based on the findings from the study presented in Chapter 3, I contributed a set of design opportunities and recommendations for technologies to help WSAR workers and teams more effectively communicate and share information with each other remotely. These design opportunities and recommendations were presented at the end of Chapter 3, and are also listed in Section 7.1 under Research Problem 2.

From these design opportunities and recommendations, I also presented early design ideas and sketches in Chapter 4 and illustrated, through the design of RescueCASTR, how a technology platform for the WSAR command post can be designed to provide WSAR commanders with contextual awareness of field teams and their activities, thus acting as an illustration of how new communication modalities and information channels can address some of the challenges and goals presented in Chapter 3.

Through the evaluation of RescueCASTR (Chapter 5), I then presented a new series of insights and further lessons to inform the design of technologies for WSAR remote collaboration.

Contribution 3: *A prototype system to help WSAR commanders build and maintain awareness of field teams and their activities.*

In Chapter 4, I presented RescueCASTR, an interface for the WSAR command post designed to enhance the WSAR Command team's awareness of what is happening in the field, including environmental conditions in the field and teams' activities and statuses. It does this through aggregating existing communication channels and information sources into a single interface, where it is presented geospatially and temporally in relation to a map and timeline, and by providing an additional implicit visual data channel (body-camera streams) that acts as a 'bridge' between the multiple layers of 'focus plus context' provided by the other data channels.

Contribution 4: *Insight on how WSAR work practices could be impacted by novel collaboration interfaces and new information-sharing modalities.*

Through the evaluation of the RescueCASTR interface (Chapter 5), I presented a set of insights on how introducing new implicit information channels such as live feeds from body cameras could impact WSAR collaborative practices, including the balance of responsibility between field teams and Command, and the reduced need for explicit communications via radios and cell phones.

In addition to these contributions, this dissertation highlights the following design lessons for building technologies for remote collaboration in WSAR and other activities involving remote collaboration across multiple teams or endpoints moving around a large geographic environment:

- **Design Lesson 1:** Design to bridge the perspectives of Command and the field.
- **Design Lesson 2:** Design to enhance non-verbal, implicit, and automatic information sharing.
- **Design Lesson 3:** Design to balance the burden of responsibility between Command and field teams.
- **Design Lesson 4:** Design to allow Commanders to triangulate focus plus context from multiple information sources of varying depth and breadth.
- **Design Lesson 5:** Design to aggregate information geospatially and temporally.

As well as the following lessons for evaluating new interfaces for emergency-response and other serious activities via remote simulation-based user studies:

- **Method Lesson 1:** Scenario- and roleplay-based evaluation techniques can be beneficial for evaluating a new user interface.
- **Method Lesson 2:** Base study scenarios on real-world incidents experienced by the target user group.

- **Method Lesson 3:** Use scenarios that are both useful for answering the research questions and ecologically valid.
- **Method Lesson 4:** Seek feedback on study scenarios from domain experts in the target user group, specifically on their realism.
- **Method Lesson 5:** Consider employing a think-aloud process, especially if participants are working alone and not communicating/interacting with other participants.
- **Method Lesson 6:** Interview participants to gauge their thoughts about how they might imagine or speculate the interface being used in their actual work.

Beyond WSAR, this dissertation contributes to Human-Computer Interaction (HCI) and CSCW an enhanced understanding of how to design technologies to support awareness, team cognition, and shared mental models in command-and-control activities where sub-teams or collaborators are scattered and moving around large environments (of several hundred to several thousand square kilometres in area) across large spans of time (several hours to several days). While there are some differences between WSAR and other command-and-control activities in terms of the sizes of the teams, geographic areas, and time spans, I hope other researchers can find value in the findings of this work and scale the insights up or down to their specific context of study.

7.3 LIMITATIONS AND FUTURE WORK

While this dissertation research has opened up the design space for WSAR remote and distributed collaboration, it has not been without its limitations. In this section, I outline these limitations as well as my recommendations for future work in this space.

I recommend that future work look into other WSAR contexts beyond just those in Canada, as differences in contexts could potentially reveal newer insights. Most of my participants from both studies were from agencies based near small towns in mountainous or forested areas. Some were from more remote regions that see fewer tourists, and a few were from agencies near large metropolitan cities or near towns that see many tourists engaging in outdoor activities. Moreover, while WSAR protocols vary slightly across Western countries, they may differ quite widely in non-Western contexts.

The demographics of Study 1 were largely limited to older men (average age of about 50 years), given that this demographic is prevalent in WSAR in Canada. Studying more women or younger WSAR members who are more technology literate could reveal different communication and technology-use patterns. Similarly, given that most of my participants received the same or similar WSAR training (under the same set of guidelines), their mindsets about how things should be done in WSAR may have been limited as a result of this. Thus, I recommend future work include a broader set of participants, and also take into account those who could participate in WSAR in the future (rather than just those who participate in it now).

The observation from Study 1 was centred around a single mock-search based on a scenario involving a search for multiple missing people. While this scenario was designed to be complex, to train WSAR workers in multiple aspects of their work and to expose them to a variety of things they could encounter in a real operation, I recognize that this does not cover the complete scope of possible WSAR incidents. Though this observation is coupled with interviews with WSAR workers about their past experiences, I recommend future studies in this space explore other types of WSAR scenarios; e.g., usage in different types of environments, rescue-only operations, and searches for single subjects.

I ran Study 2 solely with SAR managers in a completely simulated context. While the early insights provided by this study's findings can be useful for design and considerations of workers' roles and responsibilities, I have yet to deeply gauge the perspectives of field workers and explore this domain from the perspective of working in the field. Even though most WSAR managers, and indeed all of my participants from Study 2, have experience working as field workers, it would be beneficial to gauge thoughts and perceptions from the perspective of working in the field. Additionally, by having WSAR workers collaborate on an organized searching task or mock-WSAR activity in the outdoors, we could find out more about the nuances of how they actually interact with each other when they have body cameras and a system like RescueCASTR on hand. I would recommend these explorations as future work.

7.4 CLOSING REMARKS

This dissertation contributes to our understanding of how researchers and technology designers should approach creating technologies for remote collaboration in high-stakes situations where multiple teams or individuals are moving around a large geographic environment and sharing information in relation to that large environment. This work specifically focuses on the needs and practices of WSAR teams and professionals, but the findings and insights could be applied to the design of technologies for other similar command-and-control activities such as disaster response, wilderness firefighting, police work, or other types of SAR (e.g., urban SAR or combat SAR). The research conducted was qualitative and exploratory in nature, as it was aimed at understanding the unique needs and challenges of a specialized user group, and on exploring and learning about how we should design user interfaces to achieve some of their unique needs. While there are still many opportunities for future work in this area, I hope the lessons from this dissertation provide a basis for understanding how to design better user-interface technologies for WSAR, as well as for more clearly understanding the potential opportunities and challenges that new technologies could bring to WSAR work practices, so that WSAR agencies can make the best use of newer remote-collaboration modalities in their work. I also hope the lessons from this dissertation provide CSCW and HCI researchers with a more solid understanding of how teamwork plays out in activities that involve multiple teams and individuals working together across large geographic environments, as well as of how technologies can be better designed to support such activities.

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A

INVESTIGATIVE STUDY MATERIALS

This appendix contains the study materials for the first study of my dissertation: the investigative study presented in Chapter 3. These materials consist of the following:

- Interview consent form
- Observation consent form
- Pre-study survey
- List of interview questions for field workers and field team leaders
- List of interview questions for Command workers
- Recruitment notice
- Recruitment poster
- Recruitment social media advertisement

A.1 INTERVIEW CONSENT FORM

UNIVERSITY OF CALGARY

SFU SIMON FRASER UNIVERSITY
ENGAGING THE WORLD

Informed Consent Form

Research Project Title:
Investigating Search-and-Rescue Practices for the Design of Tools for Search-and-Rescue Communication, Coordination, and Information Sharing

University of Calgary Ethics ID: REB17-1020

Simon Fraser University Ethics ID: 2017s0242

Investigators:

- Brennan Jones
  University of Calgary; Simon Fraser University
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- Dr. Anthony Tang
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- Dr. Carman Neustaedter
  Simon Fraser University
  [redacted], carman@sfu.ca

This consent form, a copy of which is made available to you, is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask the investigator(s). Please take the time to read this carefully and to understand the information.

The University of Calgary Conjoint Faculties Research Ethics Board and the Simon Fraser University Office of Research Ethics have approved this research study.

Purpose:
The purpose of this study is to understand how wilderness search-and-rescue (SAR) workers communicate, coordinate, and share information while responding to an incident, in order to design technologies that better support wilderness SAR workers in these actions.

Participant Recruitment and Selection:
To be recruited for this study, you must be over 19 years of age and work or volunteer as a wilderness SAR team member, team leader, or manager; or you must be completing wilderness SAR training.

Study Method:
You will participate in a one-on-one interview. The interview will take place either face to face in a non-public location of your choosing, over the telephone, or via a video call (e.g., Skype). We will ask you questions about your SAR communication practices, your communication needs, how you use current technology to communicate, the challenges you face, and how you overcome such challenges. We may also ask you to walk us through typical scenarios (could be real or hypothetical). The interview will take no more than one hour.

Benefits and Risks:
You will not benefit directly by participating in the study. The risks of the study are expected to be minimal. We ask that you do not to reveal confidential information about specific incidents (e.g., victim names).

We ask that you do not talk about things that you do not feel comfortable discussing. We may ask you to recall past incidents that you have experienced while involved in SAR. If any of these experiences involved a traumatic event, we recognize that there is a risk that you might feel distress or discomfort as a result of recalling the experience. If you think this might be a problem, please bring it to our attention as soon as possible. We will avoid discussing topics that could cause you distress. In addition, attached at the end of this form is a list of medical and counselling services that you may contact in case of distress.

If you agree to participate, you will be free to withdraw at any time for any reason. Data collected up to that withdrawal point will be retained and used by the researchers only if you give us permission to do so. Data can be withdrawn up to fourteen (14) days after it is collected.

Your decision to participate will have no impact on your employment, and employers and organizations (such as the one(s) that you belong to) will not be told whether or not you've chosen to or been selected to participate.

Research results, such as published papers, can be obtained by contacting any of the investigators:

- Brennan Jones [redacted], bdgjones@ucalgary.ca
- Dr. Anthony Tang [redacted], tonyt@ucalgary.ca
- Dr. Carman Neustaedter [redacted], carman@sfu.ca

What Happens to the Information I Provide?:
No one except the researchers and their assistants will be allowed to see or hear any of your data.

Confidentiality will be strictly maintained. Any data collected will be labeled with an anonymous participant ID.

We will obtain permission from you to collect data in the form of researchers' notes, video/audio recordings, photos of artifacts (e.g., drawings) produced by you during the interview, and brief survey responses from you. Video and images will be recorded in a manner so that your identity is not revealed (e.g., if you give us permission to record video, we will primarily capture video of you from behind or from below the shoulders, to hide your face). Confidential data within the images and video will be masked (e.g., faces, clothing, and other recognizable features will be blurred or removed) to obscure it.

Refusal to participate or withdrawal/dropout after agreeing to participate will not have an adverse effect or consequences on you.

All information collected will be anonymized. No identifying information will be kept alongside the data. The collected information will be digitally recorded and transcribed. After the audio/video is transcribed, we will destroy the recordings. The data will be kept on a secure cloud server hosted at either the University of Calgary or Simon Fraser University until 2022 or until the study analysis is completed. At this point, it will be permanently destroyed.

Public presentations of the results will primarily present the results in an anonymized form. Where your individual data is disclosed, such as exemplar comments via quotes, we will ensure that the selected data does not suggest your identity.

Acceptance Checklist:

Please put a check mark on the corresponding lines. All items are optional.

I agree to participate in the interview and allow the research team to write down and take notes on my responses.	YES __	NO __
I agree to let audio of the interview be recorded. This audio will be transcribed by the study team immediately; and after transcription, the recording will be destroyed.	YES __	NO __
I agree to let my responses during the interview be directly quoted, anonymously, in presentation of the research results. Any confidential information contained in the quotes will be removed.	YES __	NO __
(Applies only to interviews conducted in person or via video calling.) In addition to audio, I agree to let video of the interview be recorded, in order to capture gestures or other actions that I make to explain a concept or tell a story. This video will be transcribed by the study team immediately; and after transcription, the recording will be destroyed.	YES __	NO __
(Applies only to interviews conducted in person or via video calling.) I agree to let photos of any artifacts I produce during the interview (e.g., drawings on a whiteboard, to tell a story or explain a concept) be taken and used for analysis by the study team. After analysis, these photos will be destroyed.	YES __	NO __

Acceptance of this Form:
Your signature on this form indicates that you (1) understand to your satisfaction the information provided to you about your participation in this research project, and (2) agree to participate as a research participant.

You are free to withdraw from this research project at any time up to fourteen (14) days after your data is collected. You should feel free to ask for clarification or new information throughout your participation.

To accept this form, please write your name, date, and signature below.

Name: _________________________________

Signature: _________________________________

Date: _________________________________
MM/DD/YYYY

Questions/Concerns:
If you have any questions about the study, please contact Brennan Jones at bdgjones@ucalgary.ca, Dr. Anthony Tang at tonyt@ucalgary.ca, or Dr. Carman Neustaedter at carman@sfu.ca.

If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, please contact an Ethics Resource Officer, Research Services Office, University of Calgary at 403-210-9863 or cfreb@ucalgary.ca; or Dr. Jeffrey Toward, Director, Office of Research Ethics at Simon Fraser University at jtoward@sfu.ca or 778-782-6593.

A copy of this consent form has been given to you to keep for your records and reference. The investigator has kept a copy of the consent form.

Health Contacts:

The following is a list of services that you may contact in case you feel distressed or you need to seek trauma counselling or medical information.

British Columbia, province-wide:

- **Crisis Centre BC (telephone counselling):** 604-872-3311
  https://crisiscentre.bc.ca/

- **HealthLink BC (information):** 8-1-1
  https://www.healthlinkbc.ca/

Vancouver area:

- **Willow Tree Counselling (Vancouver):** 604-521-3404
  https://willowtreecounselling.ca/areas-of-practice/post-traumatic-stress-disorder/

- **Jericho Counselling (Burnaby):** 604-537-4246
  http://www.jerichocounselling.com/counselling-services/trauma/

- **Turning Point Therapy (Greater Vancouver):** 604-638-7221
  http://trauma-vancouver.com/

- **Kevin Klassen Counselling Services (Langley):** 778-240-5794
  http://www.klassentherapy.com/

Alberta, province-wide:

- **AHS Mental Health Help Line (telephone counselling):** 877-303-2642
  http://www.albertahealthservices.ca/info/service.aspx?id=6810

- **Health Link Alberta (information):** 8-1-1
  http://www.albertahealthservices.ca/assets/healthinfo/link/index.html

Calgary area:

- **Distress Centre (telephone counselling):** 403-266-4357
  http://www.distresscentre.com/

- **Calgary Counselling Centre (trauma counselling and information):** 403-691-5991
  https://calgarycounselling.com/

Edmonton area:

- **CMHA Edmonton Distress Line (telephone counselling):** 780-482-4357
  https://edmonton.cmha.ca/programs-services/distress-line/

- **The Grief & Trauma Healing Centre (trauma counselling):** 780-288-8011
  http://www.healmyheart.ca/

A.2 OBSERVATION CONSENT FORM

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Informed Consent Form

Research Project Title:
Investigating Search-and-Rescue Practices for the Design of Tools for Search-and-Rescue Communication, Coordination, and Information Sharing

University of Calgary Ethics ID: REB17-1020

Simon Fraser University Ethics ID: 2017s0242

Investigators:

- Brennan Jones
  University of Calgary; Simon Fraser University
  bdgjones@ucalgary.ca

- Anthony Tang
  University of Calgary
  [redacted], tonyt@ucalgary.ca

- Carman Neustaedter
  Simon Fraser University
  [redacted], carman@sfu.ca

This consent form, a copy of which is made available to you, is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask the investigator(s). Please take the time to read this carefully and to understand the information.

The University of Calgary Conjoint Faculties Research Ethics Board and the Simon Fraser University Office of Research Ethics have approved this research study.

Purpose
The purpose of this study is to understand how wilderness search-and-rescue (SAR) workers communicate, coordinate, and share information while responding to an incident, in order to design technologies that better support wilderness SAR workers in these actions.

Participant Recruitment and Selection
To be recruited for this study, you must be over 19 years of age and work or volunteer as a wilderness SAR team member, team leader, or manager; or you must be completing wilderness SAR training.

Study Method
We will observe you as you participate in a SAR training activity. This will help us understand how SAR workers are coordinated, how they communicate and share information with each other, how they give and receive instructions, what they need to perform their duties, as well as what they need to successfully locate a victim in distress.

Benefits and Risks
You will not benefit directly by participating in the study. The risks of the study are expected to be minimal. We will not ask you to do anything that you would not otherwise do during your training activity.

If you agree to participate, you will be free to withdraw at any time for any reason. Data collected up to that withdrawal point will be retained and used by the researchers only if you give us permission to do so. Data can be withdrawn up to fourteen (14) days after it is collected.

Your decision to participate will have no impact on your employment, and employers and organizations (such as the one(s) that you belong to) will not be told whether or not you've chosen to or been selected to participate.

Research results, such as published papers, can be obtained by contacting any of the investigators:

- Brennan Jones bdgjones@ucalgary.ca
- Anthony Tang [redacted], tonyt@ucalgary.ca
- Carman Neustaedter [redacted], carman@sfu.ca

What Happens to the Information I Provide?
No one except the researchers and their assistants will be allowed to see or hear any of your data.

Confidentiality will be strictly maintained. Any data collected will be labeled with an anonymous participant ID.

We will obtain permission from you to collect data in the form of researchers' notes, video/audio recordings, photos, and brief survey responses from you. Video and images will be recorded in a manner so that your identity is not revealed (e.g., we will primarily capture video/images of you from behind or from below the shoulders, to hide your face). Confidential data within the images and video will be masked (e.g., faces, clothing, and other recognizable features will be blurred or removed) to obscure it.

If you choose not to consent to having video of you recorded, then we will not directly record video of you. Any indirect recordings of you (e.g., appearing in the background of a video while we directly film another participant) will not be used in the research and will be destroyed.

Refusal to participate or withdrawal/dropout after agreeing to participate will not have an adverse effect or consequences on you.

All information collected will be anonymized. No identifying information will be kept alongside the data. The data will be kept on a secure cloud server hosted at either the University of Calgary or Simon Fraser University until 2022 or until the study analysis is completed. At this point, it will be permanently destroyed.

Public presentations of the results will primarily present the results in an anonymized form. Where your individual data is disclosed, such as exemplar comments via quotes, we will ensure that the selected data does not suggest your identity.

Acceptance Checklist:

Please put a check mark on the corresponding lines. All items are optional.

I agree to let the research team observe and take notes on my actions and conversations during the training activity.	YES ___	NO ___
I agree to let video of my actions during the training activity be recorded. All identifiable and confidential information that appears in the video will be removed, masked, or blurred before post-analysis is done. The video will be destroyed immediately after analysis is complete.	YES ___	NO ___
I agree to let my conversations during the training activity be directly quoted, anonymously, in presentation of the research results. Any identifiable or confidential information contained in the quotes will be removed.	YES ___	NO ___

Acceptance of this Form:
Your signature on this form indicates that you (1) understand to your satisfaction the information provided to you about your participation in this research project, and (2) agree to participate as a research participant.

You are free to withdraw from this research project at any time up to fourteen (14) days after your data is collected. You should feel free to ask for clarification or new information throughout your participation.

To accept this form, please write your name, date, and signature below.

Name: _________________________________

Signature: _________________________________

Date: _________________________________
MM/DD/YYYY

Questions/Concerns:

If you have any questions about the study, please contact Brennan Jones at bdgjones@ucalgary.ca, Anthony Tang at tonyt@ucalgary.ca, or Carman Neustaedter at carman@sfu.ca.

If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, please contact an Ethics Resource Officer, Research Services Office, University of Calgary at 403-210-9863 or cfreb@ucalgary.ca; or Dr. Jeffrey Toward, Director, Office of Research Ethics at Simon Fraser University at jtoward@sfu.ca or 778-782-6593.

A copy of this consent form has been given to you to keep for your records and reference. The investigator has kept a copy of the consent form.

A.3 PRE-STUDY SURVEY

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Pre-Study Survey

Please answer the following quick questions related to demographics, your role in search and rescue, and your level of experience and training in search and rescue.

If there are any questions that you do not wish to answer for any reason, you may leave them blank.

Age: __________

Gender: ___________________________

Primary role in search and rescue (SAR): ____

Years of training in SAR (e.g., classes, mock searches, other training activities): __________

Years of work experience in SAR: __________

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Title of Study: Investigating Search-and-Rescue Practices for the Design of Tools for Search-and-Rescue Communication, Coordination, and Information Sharing
University of Calgary Ethics Application Number: REB17-1020
Simon Fraser University Ethics Application Number: 2017s0242
Last Updated: 2018/05/23

Interview Questions for SAR Field Workers and Field Team Leaders

Introductory Questions:

Questions to Ask:

1. Please tell me what you do as a SAR worker?
2. What kind of training and experience do you have?
3. Please walk me through the most recent (or most memorable) SAR incident that you responded to (as a SAR field worker). Tell it as a story, from beginning to end.
    a. In particular, please walk me through the steps that you took to communicate with your team members, communicate/share information with command, maintain situation awareness, and receive and follow instructions from command.

Receiving and Making Sense of Information/Instructions from Command:

Questions to Ask:

4. Tell me about a situation (real) when you were very successful at receiving, understanding, and following instructions from command.
    a. What went right?
    b. Why did things go right?
5. Tell me about a situation (real) when you were not successful at receiving, understanding, or following instructions from command (due to communication breakdowns).
    a. What was the problem?
    b. Why was it a problem?
    c. What did you try to do (if anything) to alleviate the problem(s)?

Checklist:

- How do you receive and make sense of instructions from command?
- What types of instructions do you receive from command (while out in the field and during briefing)?
    - Environmental information?
    - Status updates?
    - Clues?

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- Others?
- What types of information/instructions do you *want to* receive from command?
- Is there any information that you want to receive from command that you cannot receive or cannot make sense of easily?
  - What information?
  - Why can you not receive it or make sense of it?
  - Why do you wish to receive it or make sense of it?
- What role does technology (current technology) play in helping you receive and make sense of information/instructions from command?
  - How does it help?
  - How does it hinder?
- What role do others (e.g., your team members) play in helping you receive and make sense of information/instructions from command?
- What challenges do you face in receiving and making sense of information/instructions from command?
  - What do you do to try to overcome these challenges?
- Your actions (or your teams' actions) in relation to the search response as a whole…

Giving Information to Command:

Questions to Ask:

6. Tell me about a situation (real) when you were very successful at giving information to command.
   a. What went right?
   b. Why did things go right?
7. Tell me about a situation (real) when you were not successful at giving information to command (or in which it was challenging to do so).
   a. What was the problem?
   b. Why was it a problem?
   c. What did you try to do (if anything) to alleviate the problem(s)?

Checklist:

- How do you give information to command?
- What kinds of information do you give to command? How do you do so?
- Is there any information that you wish you could share with command that you cannot (or is difficult to do so)?
  - What information?
  - Why can you not share this information?
  - Why do you wish to share this information?
- What roles does technology (e.g., current technology/equipment) play in helping you give information to command?
  - How does it help?
  - How does it hinder?
- What role do others (e.g., your team members) play in helping you give information to command?

- What challenges do you face in giving information to command?
    - What do you do to try to overcome these challenges?

Other Questions (ask only if time permits, and if not already answered):

8. What are the essential communication skills that you feel you need as a SAR worker?
9. What do you think are the essential ingredients to a ‘successful’ search?
    a. What is needed in terms of technology, communication, awareness, etc.?
    b. Does this vary across situations?
10. What tools do you use to communicate, coordinate, and make sense of incoming information during an SAR mission?
    a. How do you use these tools?
    b. When do these tools work well for you?
    c. When do you face challenges using these tools?

Closing:

11. Anything else you would like to share?

A.5 Interview Questions for Command Workers

Title of Study: Investigating Search-and-Rescue Practices for the Design of Tools for Search-and-Rescue Communication, Coordination, and Information Sharing
University of Calgary Ethics ID: REB17-1020
Simon Fraser University Ethics ID: 2017s0242
Last Updated: 2018/05/08

Interview Questions for SAR Managers

Introductory Questions:

Questions to Ask:

1. Please tell me what you do as a SAR manager?
2. What kind of training and experience do you have?
3. Please walk me through the most recent (or most memorable) SAR incident that you responded to (as a SAR manager). Tell it as a story, from beginning to end.
   a. In particular, please walk me through the steps that you took to maintain situation awareness, give instructions/information to searchers in the field, and receive and understand information from searchers in the field.

Situation Awareness:

Questions to Ask:

4. Tell me about a situation (real) when you were very successful at maintaining situation awareness.
   a. What went right?
   b. Why did things go right?
5. Tell me about a situation (real) when you were not successful at maintaining situation awareness (or in which it was challenging to do so).
   a. What was the problem?
   b. Why was it a problem?
   c. What did you try to do (if anything) to alleviate the problem(s)?

Checklist:

- ☐ How do you maintain situation awareness?
- ☐ What role does technology (e.g., current technology/equipment) play in helping you build and maintain situation awareness?
  - o How does it help?
  - o How does it hinder?
- ☐ What role do others (e.g., people in the field, others on the management team) play in helping you build and maintain situation awareness?

1

- What challenges do you face in building and maintaining situation awareness?
    - What do you do to try to overcome these challenges?

Giving Instructions/Information to Field Workers:

Questions to Ask:

6. Tell me about a situation (real) when you were very successful at giving instructions and/or information to field workers.
    a. What went right?
    b. Why did things go right?
7. Tell me about a situation (real) when you were not successful at giving instructions and/or information to field workers (or in which it was challenging to do so).
    a. What was the problem?
    b. Why was it a problem?
    c. What did you try to do (if anything) to alleviate the problem(s)?

Checklist:

- How do you give instructions to field workers?
- What kinds of information and instructions do you give to field workers? How do you give them?
    - Navigation-related?
    - Equipment explanations?
    - Safety information?
    - Others?
- Is there any information that you wish you could share with field workers that you cannot?
    - What information?
    - Why can you not share this information?
    - Why do you wish to share this information?
- What roles does technology (e.g., current technology/equipment) play in helping you give information/instructions to field workers?
    - How does it help?
    - How does it hinder?
- What role do others (e.g., people in the field, others on the management team) play in helping you give information/instructions to field workers?
- What challenges do you face in giving instructions/information to field workers?
    - What do you do to try to overcome these challenges?
- During a typical mission, to what extent do you want your field workers to be aware of the actions, statuses, and communications of all other field teams?
    - How necessary is this?

Receiving and Making Sense of Information from Field Workers:

Questions to Ask:

8. Tell me about a situation (real) when you were very successful at receiving and making sense of information from field workers.
   a. What went right?
   b. Why did things go right?
9. Tell me about a situation (real) when you were not successful at receiving and making sense of information from field workers (or in which it was challenging to do so).
   a. What was the problem?
   b. Why was it a problem?
   c. What did you try to do (if anything) to alleviate the problem(s)?

Checklist:

- How do you receive and make sense of information from field teams/searchers?
- What types of information do you receive from field teams/searchers?
  - Environmental information?
  - Status updates?
  - Clues?
  - Others?
- What types of information do you *want to* receive from field teams/searchers?
- Is there any information that you want to receive from field workers that you cannot receive or cannot make sense of easily?
  - What information?
  - Why can you not receive it or make sense of it?
  - Why do you wish to receive it or make sense of it?
- What role does technology (current technology) play in helping you receive and make sense of information from field teams/workers?
  - How does it help?
  - How does it hinder?
- What role do others (e.g., people in the field, others on the management team) play in helping you receive and make sense of information from field teams/searchers?
- What challenges do you face in receiving and making sense of information from field workers?
  - What do you do to try to overcome these challenges?
- How do you and your management team know where your field teams are located and what they are doing? How easy is it to obtain this information?
- Do you wish you knew more about where your field teams are located and what they are doing? Do you wish it was easier to obtain this information? Why or why not?

Receiving and Making Sense of Information from External Sources:

Questions to Ask:

10. Tell me about a situation (real) when you were very successful at receiving and making sense of information from external sources (e.g., weather, police, other SAR organizations, witnesses, victim's family/friends, etc.).
    c. What went right?
    d. Why did things go right?

11. Tell me about a situation (real) when you were not successful at receiving and making sense of information from external sources (or in which it was challenging to do so).
    d. What was the problem?
    e. Why was it a problem?
    f. What did you try to do (if anything) to alleviate the problem(s)?

Checklist:

- How do you manage and make sense of information from external sources (e.g., weather, police, other SAR organizations, witnesses, victim's family/friends, etc.)?
- How do you use this information to make decisions and plan the SAR response?
- Which of this information do you communicate with others (e.g., field workers, other SAR managers)?
    - Why do you communicate this information to them?
    - How do you communicate this information?

Collaboration with Other SAR Organizations:

Questions to Ask:

12. Have you ever been involved in a large search in which you had to collaborate with other SAR organizations? Tell me about it.

Checklist:

- How do different SAR organizations responding to a single incident communicate, collaborate, and share information between each other?
    - What communication, collaboration, and information-sharing challenges occur when multiple SAR organizations respond to a single incident?

Other Questions (ask only if time permits, and if not already answered):

13. What are the essential communication skills that you need as a SAR manager?
14. What are the essential communication skills that you want SAR field workers to have?
15. What are the essential ingredients to a 'successful' search?
    a. What is needed in terms of technology, communication, awareness, etc.?
    b. Does this vary across situations?
16. What tools do you use to communicate, coordinate, and make sense of incoming information during an SAR mission?
    a. How do you use these tools?
    b. When do these tools work well for you?
    c. When do you face challenges using these tools?

Closing:

17. Anything else you would like to share?

A.6 RECRUITMENT NOTICE

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ENGAGING THE WORLD

Study Recruitment Notice

Investigating Search-and-Rescue Practices for the Design of Tools for Search-and-Rescue Communication, Coordination, and Information Sharing

I am a PhD student at the University of Calgary, and a visiting student at Simon Fraser University. As part of my research, I am conducting studies of wilderness search-and-rescue practices in order to understand how we can design and build user-interface technologies to better support distributed collaboration in wilderness search and rescue. If you are a wilderness search-and-rescue worker or volunteer, or you train or manage wilderness search-and-rescue workers, we would be interested in talking with you about your work practices. If you are a search-and-rescue manager or team leader, we are interested in learning how you instruct, coordinate, and communicate with your team during a search. If you are a wilderness search-and-rescue team member, we are interested in learning about how you communicate with your fellow team members, how you receive and follow instructions from superiors, and how you communicate with and provide information to your team leader or search-and-rescue manager.

For more details or to participate, please email me at bdgjones@ucalgary.ca.

Thank you!

Sincerely,

Brennan Jones

PhD Student, Department of Computer Science, University of Calgary
Visiting PhD Student, School of Interactive Arts and Technology, Simon Fraser University

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The University of Calgary Conjoint Faculties Research Ethics Board and the Simon Fraser University Office of Research Ethics have approved this research study.

University of Calgary Ethics ID: REB17-1020
Simon Fraser University Ethics ID: 2017s0242

A.7 RECRUITMENT POSTER

A.8 RECRUITMENT SOCIAL MEDIA ADVERTISEMENT

UNIVERSITY OF CALGARY

SFU SIMON FRASER UNIVERSITY ENGAGING THE WORLD

Title of Study: Investigating Search-and-Rescue Practices for the Design of Tools for Search-and-Rescue Communication, Coordination, and Information Sharing
University of Calgary Ethics Application Number: REB17-1020
Simon Fraser University Ethics Application Number: 2017s0242
Name of Principal Investigator: Brennan Jones
Department, School or Faculty: School of Interactive Arts & Technology, SFU
Document Version: 2, 13 August 2017

Appendix: Social Media Advertisements

Example post: "Do you work or volunteer in search and rescue? Please help our research. Contact bdgjones@ucalgary.ca to participate in an interview."

B

INVESTIGATIVE STUDY CODES

This appendix contains the complete listing of the codes from the analysis process for the data from the first study of my dissertation: the investigative study presented in Chapter 3.

Axial Code	Open Code
Awareness	Being on the same page
	Higher-level awareness
	Lack of awareness
	Lower-level awareness
	Staying connected with and aware of others
Efficiency of Working	Efficient use of resources (equipment, personnel, etc.)
	Multitasking
Information	Analysing and investigating information
	Changing or updating information
	Confidentiality of information or communication
	Conflicting information
	Determining importance of information
	Discussion of information
	Filtering information
	Higher-level mission information
	Information about subject(s)
	Information overload (or potential for it)
	Location information
	Managing incoming information
	Medical information
	Receiving information
	Referring back to saved or historical information
	Requesting information
	Saving information
	Scene information (what's at a location)
	Sending information
	Too little information
	Understanding information
Instructions	Giving instructions
	Receiving instructions
	Requesting instructions
	Understanding instructions
Nature of SAR	Nature of SAR responses
	Search strategy
	Standardization of work protocols
Perspectives	Differing perspectives and views
	Providing different perspectives and views
	Requesting additional perspectives
Planning and Decision Making	Decision making
	Planning
Profile of Worker, Team, or Agency	Nature of team or agency makeup
	Skill and experience level of personnel
Requesting More of Something	Requesting additional personnel
	Requesting additional resources
Roles and Tasks	Changeover
	Delegation of responsibilities, resources, personnel, communications, etc.
	Role assignments

Axial Code	Open Code
	Task assignments
Social & Emotional Factors	Anxiety from isolation or lack of awareness
	Bliss of ignorance
	Liability
	Motivation from awareness
	Social interaction
	Stress and pressure
Statuses	Availability of resources
	Availability of volunteers (personnel)
	Progress of the search
	Requesting status of personnel
	Status of equipment
	Status of personnel
	Status of vehicles
Technology	Benefits of technology
	Ease or complexity of use
	Limitations of technology
	Medium of communication
	Technology in use

C

RESCUECASTR USER STUDY MATERIALS

This appendix contains the study materials for the second study of my dissertation: the remote simulation user study for evaluating RescueCASTR, presented in Chapter 5. These materials consist of the following:

- Consent form
- Verbal protocol
- Pre-study demographic survey
- Sample think-aloud prompts and questions
- Interview guide
- Recruitment notice
- Recruitment poster
- Recruitment email
- Recruitment social media advertisement
- Study scenario description sheets

C.1 CONSENT FORM

Informed Consent Form

Research Project Title:
Designing Mobile-Video-Conferencing Technologies for Multi-Party Remote Collaboration

Ethics ID: REB20-0532

Investigators:

- Brennan Jones
  PhD Candidate, University of Calgary
  bdgjones@ucalgary.ca
- Dr. Anthony Tang
  Associate Professor, University of Toronto
  Adjunct Associate Professor, University of Calgary
  tonytang@utoronto.ca
- Dr. Carman Neustaedter
  Professor, Simon Fraser University
  carman@sfu.ca
- Dr. Ehud Sharlin
  Professor, University of Calgary
  ehud@cpsc.ucalgary.ca

This consent form, a copy of which is made available to you, is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask the investigator(s). Please take the time to read this carefully and to understand the information.

The University of Calgary Conjoint Faculties Research Ethics Board has approved this study.

Purpose:
The purpose of this study is to help us understand how to build better video-conferencing technologies for distributed collaboration across large geographic spaces. We are designing a video-conferencing interface that helps users understand the visual content of a teammate's surroundings in relation to the larger environment, thus helping them understand that teammate's current situation in relation to the bigger picture. This interface is being designed to support collaboration in activities where a commander instructs and coordinates several field workers; activities such as search and rescue and disaster response.

We are evaluating a set of interface-design choices for this type of system. We are running a study to investigate how commander users might use our video-conferencing interface to try to understand the current status of a collaborative team activity taking place in a large geographic area, where there are multiple field workers scattered around the area. From this understanding, we are looking to learn how these types of mobile-video-conferencing systems in general can be built to better support such collaborative activities in large outdoor environments.

Participant Recruitment and Selection:
To be recruited for this study, you must be 18 years of age or older.

Page 1 of 5

Study Method:
You will use our interface to explore pre-recorded videos from a simulated wilderness-search-and-rescue operation taking place in a provincial park. The idea is that these videos would have been live-streamed by search teams in the park over the course of the operation and from different locations in the park. As the 'Commander', your task is to try to understand the 'current status' of the search operation (e.g., which teams are deployed, what areas have been searched, etc.) as quickly and efficiently as possible. You will have some time to explore the data using the interface. While you are doing this, you will be connected to the study investigator via an audio call (via telephone, Skype, or other software), and encouraged to 'think aloud' as you use and explore the interface. Afterward, you will be asked a set of questions regarding the status of the search, to test your current understanding of it.

Note: we are *not* evaluating you. Instead, we are evaluating how well our interface designs help users understand and retain situation awareness and a mental model. Thus, please relax and simply enjoy yourself while you participate in the activity.

You will be asked to fill out a brief questionnaire and participate in a brief interview about your experiences.

Your participation is entirely voluntary. You may refuse to participate altogether, or may withdraw from the study at any time without penalty by stating your wish to withdraw to the researchers.

This study should take approximately one hour. You will receive remuneration in the form of $20 for your participation. You will receive this remuneration even if you choose to withdraw from the study.

Data Collection:
Should you agree to participate, you will be asked to provide your gender, age and academic major or occupation in a questionnaire. Providing this information is optional.

We will be collecting a screen recording of your interactions with the interface, as well as an audio recording of your 'think-aloud' speech/utterances while using the interface. Furthermore, we will audio-record our interview with you. The interview will be transcribed after it is recorded, and following transcription, the original audio will be destroyed. The main purpose for collecting this data is analysis of the session and the interview content. However, with your permission, we might want to use clips or stills of the screen-recorded video in presentations or other electronic media, but this can only happen with your consent. Please, indicate below if you grant us permission to use video clips or still pictures from the screen recording. Any clips or stills of the video will not be associated with your name or contact information.

There are several options for you to consider if you decide to take part in this research. You can choose all, some or none of them.

Please put a check mark on the corresponding lines. All items are optional.

I agree to let a screen recording of my interactions with the interface be collected for data analysis.	YES __	NO __
I agree to let video clips or stills from this screen recording be used for presentation of the research results. The clips or stills will not contain your name, face, or any other information about you.	YES __	NO __
I agree to let my interview responses and think-aloud speech be directly quoted, anonymously, in presentation of the research results.	YES __	NO __
I agree to let my responses in the questionnaire I fill out be collected and used for data analysis.	YES __	NO __
I agree to let my responses in the questionnaire I fill out be directly quoted, anonymously, in presentation of the research results.	YES __	NO __

Benefits and Risks:
You will not benefit directly by participating in the study. Indirectly, this research will result in design guidelines for designing systems for multi-way collaborative mobile video conferencing interfaces for large environments. This research may lead to knowledge or technologies that directly benefit search-and-rescue work. The risks of the study are expected to be minimal.

Your decision to participate will have no impact on your employment, and employers and organizations (such as the one(s) that you belong to) will not be told whether or not you've chosen to or been selected to participate.

Research results, such as published papers, can be obtained by contacting any of the investigators:

- Brennan Jones bdgjones@ucalgary.ca
- Dr. Anthony Tang tonytang@utoronto.ca
- Dr. Carman Neustaedter carman@sfu.ca
- Dr. Ehud Sharlin ehud@cpsc.ucalgary.ca

What Happens to the Information I Provide?:
You are free to withdraw from this study at any point. If this occurs, we will immediately stop collecting data from you, ensuring that only data for which you have given consent is used.

Data collected up to that withdrawal point will be retained and used by the researchers only if you give us permission to do so. Data can be withdrawn up to fourteen (14) days after it is collected.

All data received from this study will be kept for five years in a secure location. The investigators indicated on this form will have access to the raw data, as will research assistants on this project. While the exact composition of this team may change over time, the primary investigators will remain on the project.

In any reports created based on this study, you will be represented anonymously, using a pseudonym or participant number (e.g. Participant 4). With your permission (as indicated in the table above) we may use quotes from your interview or think-aloud speech, or screenshots of your session in our published results; these will not be associated with your name or contact information. No personal or confidential information will be published. Please note that once videotaped images are displayed in any public forum, the researchers will have no control over any future use by others who may copy these images and repost them in other formats or contexts, including possibly on the Internet.

Acceptance of this Form:
Your signature on this form indicates that you (1) understand to your satisfaction the information provided to you about your participation in this research project, and (2) agree to participate as a research participant.

In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from this research project at any time. You should feel free to ask for clarification or new information throughout your participation.

To accept this form, please write your name, date, and signature below.

Name: _________________________________

Signature: _________________________________

Date: _________________________________
MM/DD/YYYY

Questions/Concerns:
If you have any questions about the study, please contact Brennan Jones at bdgjones@ucalgary.ca, Dr. Anthony Tang at tonytang@utoronto.ca, Dr. Carman Neustaedter at carman@sfu.ca, or Dr. Ehud Sharlin at ehud@cpsc.ucalgary.ca.

If you have any concerns about the way you have been treated as a participant, please contact the Research Ethics Analyst, Research Services, University of Calgary at 403.220.6289 or 403.220.8640; e-mail cfreb@ucalgary.ca.

A copy of this consent form has been given to you to keep for your records and reference. The investigator has kept a copy of the consent form.

C.2 VERBAL PROTOCOL

Verbal Protocol

This script is used prior to asking the participants to sign consent forms. This is part of the consent process.

Hello. My name is [experimenter name], and I will guide you through this study. Thank you for your participation. You should feel free to ask me questions at any time.

Before we begin, you should understand that you have several rights as a participant:

- *You may withdraw from this study at any time by indicating your wish to*
- *withdraw to me or my co-investigators.*
- *No data will be used without your explicit consent, as indicated on the consent*
- *form I am about to give you.*
- *Your participation in this experiment is confidential.*

Now, please read this consent form carefully, which explains your right as a participant and the conditions of the study, and sign it if you agree with the terms. [Hand two copies of the form to each participant]

One of these copies is for you to keep for your own records.

C.3 PRE-STUDY DEMOGRAPHIC SURVEY

UNIVERSITY OF CALGARY

Title of Study: Designing Mobile-Video-Conferencing Technologies for Multi-Party Remote Collaboration
Ethics ID: REB20-0532
Name of Investigators: Brennan Jones, Anthony Tang, Carman Neustaedter, and Ehud Sharlin
Department and Institution: Department of Computer Science, Faculty of Science, University of Calgary
Document Version: 2, 20 September 2020

Appendix: Demographic Questions

Please answer the following quick questions related to demographics and your role and experience in search and rescue. If there are any questions that you do not wish to answer for any reason, you may leave them blank.

Age: __________________

Gender: ____________________

Occupation: _______________________________

Primary role in SAR: ____

Do you have experience working in the command post (e.g., as a SAR manager)? If so, how many years of experience? What role(s) have you played in the command post?:

____

____

Years of training in SAR (e.g., through classes, mock searches, or other training activities): _____

Years of experience working (i.e., responding to tasks/incidents) in SAR: _______

How many tasks/callouts per year (approximately) do you respond to as a SAR worker?: ______

C.4 SAMPLE THINK-ALOUD PROMPTS AND QUESTIONS

Title of Study: Designing Mobile-Video-Conferencing Technologies for Multi-Party Remote Collaboration
Ethics ID: REB20-0532
Name of Investigators: Brennan Jones, Anthony Tang, Carman Neustaedter, and Ehud Sharlin
Department and Institution: Department of Computer Science, Faculty of Science, University of Calgary
Document Version: 1, 7 May 2020

Appendix: Questions to ask Participants in Study 1

In Study 1, the participant, acting as a SAR manager at a command post, will be asked to summarize their understanding of the 'current status' of a simulated search. The interface will present to the participant a map overview of a simulated search, showing the 'current locations' of teams, the paths they traversed, their live video feeds, past video frames, and photos and notes they have sent from different locations in the search area. They will also be asked questions to test their understanding of the 'current status' of the search. These are the types of questions that we anticipate to ask. Note that the exact questions asked might change, but will be of the same nature:

How many teams are currently in the field?

How much progress has each team made in their assigned search task?

Which team(s) have found the most clues?

Which clues, or other visual information on the map, are you most interested in? Why?

Given the current status of the search, which teams (if any) would you decide to contact right now to seek more information?

Based on the information presented, which team do you think will return to the command post sooner?

Based on the information presented, where would you deploy field teams next, to conduct a more-detailed search?

There are two purposes of asking these questions: (1) to get a sense of the user's understanding of the 'current status' of an ongoing search, as presented by our interface, (2) to give them prompts, or starting points, in exploring the data presented in our interface, and (3) to act as discussion prompts for feedback from participants and ideas for improving our interface. Participants will also be asked to 'think aloud' as they explore our interface.

C.5 INTERVIEW GUIDE

UNIVERSITY OF CALGARY

Title of Study: Designing Mobile-Video-Conferencing Technologies for Multi-Party Remote Collaboration
Ethics ID: REB20-0532
Name of Investigators: Brennan Jones, Anthony Tang, Carman Neustaedter, and Ehud Sharlin
Department and Institution: Department of Computer Science, Faculty of Science, University of Calgary
Document Version: 1, 7 May 2020

Study 1 Post-Scenarios Interview Guide

After using the interface and completing the scenarios, we will ask participants a series of questions in a semi-structured interview. These are the types of questions that we will ask.

What did you think of the interface? Was it easy to use? Was it difficult to use?

What aspects of the interface were easy/difficult to use? Why?

What elements of the interface were/were not useful to you in the tasks? Why?

- What elements were/were not useful in ***[SCENARIO]***? Why?

Which interface elements would/would not be useful to you as a SAR commander in real search activities? Why?

Is there anything not in the interface that you would like to see added to it?

Could you please tell me a story about a real incident in which communication with field teams was particularly challenging? What made communication challenging?

- If you had a stable/refined/working version of this system to use during that incident, how do you imagine it might play out?
  - Would it help?
  - Would it hinder?
  - What aspects of the interface might aid you?
  - What aspects of the interface might not be useful to you (or might hinder you)?
  - Is there anything you could think of to add to this interface that might have helped you during that incident?

Now try to imagine from the perspective of the field teams. Is there anything that you could think of to add to this system concept that might aid field teams?

- E.g., a feature on the command interface that makes it easier to communicate something to a field team.

C.6 RECRUITMENT NOTICE

Title of Study: Designing Mobile-Video-Conferencing Technologies for Multi-Party Remote Collaboration
Ethics ID: REB20-0532
Name of Investigators: Brennan Jones, Anthony Tang, Carman Neustaedter, and Ehud Sharlin
Department and Institution: Department of Computer Science, Faculty of Science, University of Calgary
Document Version: 2, 7 May 2020

We are designing a new video-conferencing interface that allow teams of people to help one another at a distance when scattered in large geographic environments. The intent is to support team activities like disaster response and search and rescue. We are looking to understand how users use this type of interface, and from this, how we can better design such interfaces.

We are looking for participants aged 18+ to help us with a preliminary test of design choices this new interface. Participants will be asked to test our interface by using it to explore pre-recorded videos from a simulated wilderness-search-and-rescue response. As part of this experience, your interactions with the interface will be screen-recorded. You will also be asked to participate in an interview at the end. This activity will not only be fun, but it will help us understand how to design better technologies for remote collaboration in emergency-response activities such as disaster response and search and rescue.

WHERE: Your own home!

TIME: Approximately 1 hour

REMUNERATION: $20/person

OTHER REQUIREMENTS: You need to have your own desktop or laptop computer (or access to a computer) with a stable Internet connection.

If you are interested in participating, or have any questions, please contact Brennan Jones (bdgjones@ucalgary.ca).

This study has been approved by the University of Calgary Conjoint Faculties Research Ethics Board (CFREB).

C.7 RECRUITMENT POSTER

UNIVERSITY OF CALGARY

LOOKING FOR WILDERNESS

SEARCH AND RESCUE WORKERS

TO TRY A NEW COMMANDER INTERFACE

We are researchers designing a new interface for wilderness search and rescue (SAR) managers to help them coordinate and communicate with field teams scattered around a large search area. We are looking for SAR workers to test this interface and help us explore usage scenarios and design choices for it. This will be an in-home study, taking place over a video call. Your participation will help us understand how to design better technologies for remote collaboration in search and rescue and other related activities.

WHO: Search and rescue workers aged 18+

WHEN: September 10 - October 4, 2020

WHERE: Your own home, via a video call

TIME: Approximately 1.5 hours

REMUNERATION: CAD$20

For more details or to sign up, please email Brennan Jones: bdgjones@ucalgary.ca.

This study has been approved by the University of Calgary Conjoint Faculties Research Ethics Board (CFREB). Ethics ID: REB20-0532

C.8 RECRUITMENT EMAIL

UNIVERSITY OF CALGARY

Title of Study: Designing Mobile-Video-Conferencing Technologies for Multi-Party Remote Collaboration
Ethics ID: REB20-0532
Name of Investigators: Brennan Jones, Anthony Tang, Carman Neustaedter, and Ehud Sharlin
Department and Institution: Department of Computer Science, Faculty of Science, University of Calgary
Document Version: 1, 7 May 2020

Appendix: Email Recruitment, Study 1

Example email body (will contain recruitment notice attached):

"I'm a PhD Candidate at the University of Calgary. As part of my research, we are designing a new video-conferencing interface that allow teams of people to help one another at a distance when scattered in large geographic environments. The intent is to support team activities like disaster response and search and rescue. We are looking to understand how users use this type of interface, and from this, how we can better design such interfaces.

We are looking for participants aged 18+ to help us with a preliminary test of design choices for this new interface. Participants will be asked to test our interface by using it to explore pre-recorded videos from a simulated wilderness-search-and-rescue response. As part of this experience, your interactions with the interface will be screen-recorded. You will also be asked to participate in an interview at the end. This activity will not only be fun, but it will help us understand how to design better technologies for remote collaboration in emergency-response activities such as disaster response and search and rescue.

You can participate in this study from your own home, as long as you have a computer and a stable Internet connection. For more details or to participate, please email bdgjones@ucalgary.ca.

We would also appreciate if you could forward this notice to anyone who you believe might be interested in participating.

Thank you!

Sincerely,

Brennan Jones
PhD Candidate, University of Calgary"

C.9 RECRUITMENT SOCIAL MEDIA ADVERTISEMENT

UNIVERSITY OF CALGARY

Title of Study: Designing Mobile-Video-Conferencing Technologies for Multi-Party Remote Collaboration
Ethics ID: REB20-0532
Name of Investigators: Brennan Jones, Anthony Tang, Carman Neustaedter, and Ehud Sharlin
Department and Institution: Department of Computer Science, Faculty of Science, University of Calgary
Document Version: 1, 7 May 2020

Appendix: Social Media Advertisements

Example post (will contain recruitment notice attached): "Do you work in search and rescue, or are you interested in video-conferencing technologies? Please help our research. Contact bdgjones@ucalgary.ca to participate in a study to evaluate a new team-based mobile-video-collaboration tool."

Scenario 1: Checking the Statuses of Teams

You and your SAR agency are in the middle of a search for Aaron, a missing 8-year-old boy (more info on Aaron below). The search has been progressing for a few hours, and you are the active SAR manager at Command.

You are currently doing a routine check of field teams' statuses, using the RescueCASTR interface. There are four teams deployed in the field at this moment. Please use the interface to check the current live body-camera footage and most up-to-date information from the teams deployed in the field to make sure that (a) all teams are safe, (b) all teams are on track to completing their assignments, and (c) to get an idea of what teams are facing.

When you are checking each team, be sure to do each of the following:

1. Check to make sure the team is following the right path.
2. Check to see if there is anything wrong (e.g., the team is not moving, or something looks unsafe).
3. Check the clues the team has found or messages they've sent, to see if anything relates to info you have on the subject (below).
4. Message the team if they are available. If you have any questions for the team, ask them. If you want to give them instructions, give them. Otherwise if everything looks okay, you could also give them words of encouragement.

About the Lost Person

Name: Aaron

Age: 8

Other info: Parents woke up at nearby campsite, didn't see him in the tent, and couldn't find him nearby. Was last wearing a blue shirt and green pyjama pants. Probably wearing white running shoes. Also often wears a custom-made puppy-dog bracelet.

Scenario 2: New Information from the Lost Person's Family

A WSAR response for a missing 15-year-old girl, named Eliza (info below), has been ongoing for 4 hours. Eliza's Dad just arrived at the Command post. He's here to share with you some information about Eliza that you didn't have before. Here's what he tells you:

- Eliza owns a blue rain jacket. She might have worn it while out, as it has rained a bit.
- Eliza likes to walk her dog, a five-year-old German Shepherd. Eliza's dog's not home right now, so she might have taken him out with her.
- Eliza is a big fan of the Japanese cartoon character Doraemon.

There are currently 3 teams deployed in the field. You can see their current locations and live body-cam footage, plus the paths they've taken and their past footage. You can also view past messages from teams and clues they have marked off. You have a few minutes of spare time. See if you can find anything in the data on the interface based on the new information Eliza's Dad gave you.

Eliza's Dad is currently waiting near the Command post. If you have any questions you'd like to ask him, ask Brennan (the study investigator), and he will respond.

If you find anything of importance, please describe how you would narrow the search based on what you find (e.g., would you tell teams to focus their search on a particular area?). Please then use the interface to message the teams to instruct them to search the new area(s).

About the Lost Person

Name: Eliza

Age: 15

Other info: Parents haven't seen Eliza since last night. They've called her friends, and they don't know her whereabouts either.

Scenario 3: Understanding Where a Team Landed

Team A is being deployed to near a mountain peak to look for a lost hiker. Given the urgency of the situation, the team needs to reach their assigned search location quickly, so they hitched a ride on a helicopter to get there. The team gathers all the necessary equipment (rope, boots, extra clothing, emergency supplies, etc.), and the team members board the helicopter and take off. Half an hour passes, and you receive a message from the team leader:

"Command, the helicopter landed us, but it might not be in the right spot."

Your job now is to figure out: (1) if Team A is where they are supposed to be, (2) if not, is there a safe path for the team to traverse to get to where they are supposed to search.

D

RESCUECASTR USER STUDY CODES

This appendix contains the complete listing of the codes from the analysis process for the data from the second study of my dissertation: the remote simulation user study for evaluating RescueCASTR, presented in Chapter 5.

Awareness
Availability and amount of information
Having more information, sooner, is better, to take action on that information sooner
Having to wait for new information
Lack of information
More information from more sources is better
Narrowing down Command's focus
Clues and messages help Command narrow down what to pay attention to in the abundance of camera footage
Using AI to analyze camera footage and inform Command about potentially notable areas
Using camera footage to narrow Command's focus
Deciding to communicate with a particular field team more because the footage and data coming from them is noteworthy
Need to send as much 'useful' info as possible in low-bandwidth situations
Pushback by some in SAR of using body cams, as it presents 'too much information'
Too much information, getting distracted
Camera footage could be a distraction
Awareness beyond sight
Awareness of activities and actions
Awareness of 'anomalies'
Awareness of features in the field
Awareness of field team deviating from what Command wants them to do
Awareness of location
Awareness of location in dead zone useful for making decisions in the moment
Awareness of progress
Awareness of safety
Awareness providing comfort
Camera footage provides awareness of a new location, to a manager who is not yet aware of that particular location
Knowing if the field team is aware of something in the camera footage
Visual awareness
Camera footage content
Camera footage content does not present 'full story'
Comparing camera footage to other data
An interface should make it easy to compare different data sources, by bringing them into one place
Comparing camera footage to maps and location data
Comparing camera footage to maps or satellite imagery to see if a team actually went off their assigned path
Comparing camera footage to maps to find new paths and other features
Comparing camera footage to satellite imagery to try to figure out what the terrain would be like in an area that has yet to be explored by field teams
Comparing camera footage to terrain (height) data
Comparing camera footage to weather and precipitation forecasts and data
Trusting information from other sources before camera footage
Trusting information from map and GPS data before camera footage
Concerns about what shows up in the camera footage
Privacy concerns with camera footage
Seeing people in camera footage

Seeing the subject in camera footage
Seeing troubling things in the camera footage
Seeing a deceased person in the camera footage
Frequency of camera images
Frequency of camera images doesn't always need to be high
Quality of camera view
Camera footage provide good views on trails
Understanding and making sense of camera footage
Brainstorming (by oneself or with others at Command) using camera footage
Camera footage allows Command to come up with their own interpretation
Getting acquainted with data
Communication challenges
Communications being time consuming
Radio dead zones
Beneficial to notify Command when a team exits a dead zone, especially if they found clues or cached
Beneficial to notify the field team when they exits a dead zone, or when their cached clues and messages have been sent or received
Seeing where team is located in radio dead zone saves Command time and effort in making calculated estimate themselves
Useful to have footage revealed after team exits radio dead zone
Reception issues
Relaying communications
Decision making
Clues and messaging are more crucial for decision making and are higher priority, body-cam footage is more for comfort and awareness of progress and features in the field (if needed)
Making decisions based on camera footage
Seeing clues can be useful for decision making
Trying to make decisions based on limited available information
Using camera footage for planning
Using camera footage to plan next actions and task assignments in current search
Ease of use of technology
Interface clutter
Practice of technical or communication skills
Technical knowledge about communications
Technology must be easy to use, especially in dire conditions. Minimize burden and responsibility on users, or have an expert dedicated to using the tech
Liability
Building 'risk avoidance' and 'checkboxes' or reminders into the system can help reduce liability
Camera footage can protect liability, 'cover one's ass'
Camera footage that 'shows the full story' could help reduce liability
Camera footage could increase liability
Having other people, 'eyes', or 'perspectives' can help reduce risks and liability
Liability is often a question of 'what did we not do'
Not worried about accountability because SAR workers are trained and follow procedures
Sharing data with others
Handing over past footage to others
Handing over footage data to law enforcement

    - Use of footage data during role changeovers
  - Sharing footage with 'experts' (medical, avalanche, etc.)
    - Sharing footage with avalanche technician
    - Sharing footage with coroner, 'declaring death by video'
    - Sharing footage with medical expert
  - Sharing live camera footage with others
    - Communicating with deployed teams about other teams' live camera footage
    - Sharing live and currently updating data with other agencies

- **Technology and workers' roles and responsibilities**
  - Adjusting roles and work practices to new technologies
    - Command's 'role', or duty or obligation to check the camera footage
      - Command isn't going to notice important clues or the subject in the footage, at least without field teams also noticing these
      - Command won't be paying a lot of detailed attention to the live camera footage all the time
    - Span of control
  - Camera footage could allow Command to do risk assessment, which in the present day is usually done by the field team
  - Camera footage saves time and effort
    - Camera footage saves time and effort for Command, as it helps them get more information without needing to bother the teams as much
    - Camera footage saves time and effort for field teams, as they don't need to check in with Command as frequently
  - Command's need vs field teams' needs
  - 'Experts' could provide field teams info from the command post
  - Extra data allows Command workers to be a 'better partner' to the field team leader
  - Field workers being happy that Command can see their situation
  - Micromanaging
    - Camera footage could fill in the gaps if field teams don't check in regularly, possibly reducing micromanaging (shifting the duty to check from the field team to Command)
    - Command disagreeing with field team leader, or trying to do TL's work
    - Trusting field team leaders to do their work properly

- **Use of past data**
  - Archiving footage and data
    - Data storage
    - Footage as evidence
  - Reviewing past data
    - Communicating with field teams about past footage
      - Field teams tell Command where, when, and what to pay attention to in camera footage
    - Reviewing past data after an incident
      - Reviewing camera footage to learn and plan for future responses
    - Reviewing past data during an incident

- **Video Insights**