Context, Uncertainty, and Interdependence: Crisis Informatics and Severe Weather Risk Communication for People with Visual Impairments

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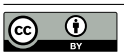
Abstract

The challenges faced by individuals with visual impairments during severe weather events are poorly understood by prevailing approaches in the fields of risk communication and crisis informatics. To develop a stronger foundation for HCI research and design in this area, we conducted interviews with adults with varying forms of visual impairment about their recent experiences during weather emergencies and the role of digital technologies in supporting actions related to disaster preparedness and safety. We draw on our findings as well as disaster research and critical disability studies to make three arguments to help orient future work. First, despite the challenges involved, efforts to improve risk communication for this audience must account for the social and infrastructural contexts that shape individuals' embodied experiences of severe weather. Furthermore, risk communication efforts must carefully balance interventions aimed at supporting recipient independence with collective or social strategies to support the goals of disability justice. Second, we suggest the potential for risk communications to nurture interdependent networks of infromation sharing and support. Finally, our study suggests the need to significantly reframe longstanding assumptions regarding the form and characteristics of uncertainty that designers should attend to as part of efforts to improve severe weather risk communication.

CCS Concepts

• **Human-centered computing → HCI theory, concepts and models**.



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1 Introduction

Severe weather events disrupt routine patterns of life and mobility, cause physical damage to buildings and infrastructure, and threaten the safety of communities and individuals. Globally, these events are predicted to increase in frequency, duration and intensity because of changes in human settlement patterns and anthropogenic climate change [25, 68]. People with disabilities are often particularly impacted by weather hazards [46, 90], and there have been increasing calls for research and practice of risk communication to pay greater attention to these inequalities [1, 40, 61, 62]. In recent years, HCI, and in particular the field of crisis informatics [65, 66, 77], has begun to investigate disaster risk communication as both an important and socially relevant problem space and as a rich and interdisciplinary field of research and design practice [7, 32, 41, 78]. As a step towards elaborating the research and design space that lies at the challenging and safety-critical intersection of crisis informatics, accessibility, and disaster risk communication, this study sought to understand the experiences of people with visual impairments (PwVI) during weather emergencies, their uses of technology in support of information access and sharing, and the forms of support they both sought after and provided to others.

Weather risk communication is a field of research and practice that focuses on communicating safety-related information to the public during the course of weather-related hazardous events

[50, 78]. Communicating risk to the public is often a difficult and potentially life-saving undertaking, such that prior work has examined how experts, such as weather forecasters and emergency managers, can convey guidance effectively to the public [78]. Weather risk communication is generally evaluated for its ability to support protective decision-making – the decisions that individuals and communities make in advance of and during disasters that impact their safety [49]. Prior work has argued that foundational HCI approaches, including human-centered design, user participation, and attention to emerging interfaces, render the field well-positioned to make important contributions to risk communication strategies and information products [8, 78], but to date there have been very few studies that seek to connect this work to the specific experiences of people with visual impairments.

Critical Disability Studies (CDS) – an area of research that concerns the lived experience of people with disabilities and the broader social landscape that helps to shape this experience [51, 55] – may offer insights into improving the efficacy and inclusivity of risk communication. Prior research in the emergency management literature has found that people with disabilities may be particularly impacted by hazardous events. For example, Connon and Hall [15] and Quigley and Lowe [71] find that hazards such as flooding, power outages, and damage to homes disproportionately affect individuals who use assistive technology or have special mobility needs. The impacts of weather emergencies may be further exacerbated for this group as they often lack access to medical care and medical supplies, accessible transportation when evacuating, and difficulty accessing shelters with services to assist individuals with special needs [15, 39, 71]. Despite the disproportionate impact hazards may have on this community, risk communication is frequently inaccessible or unusable to a wide range of abilities and informational needs [78].

To improve the conceptual foundation for future crisis informatics research and design work on this topic, our study examines severe weather risk through the lived experience of PwVI. Drawing upon a series of semi-structured interviews with 17 individuals with varying forms of vision loss, we investigate participants' experiences during severe weather. Interviews encompassed the participant's personal context, technology use, and prior experiences during severe weather events, including behavior related to information seeking and protective decision making. Through an inductive form of reflexive thematic analysis (RTA) [9, 10], we developed several key arguments from our interview data. First, we identify that navigation and mobility was rendered particularly challenging as a result of that severe weather's disruption of participants' sensory experiences and routine technology usage. Then, we show that these effects were partly determined and perpetuated by contextual factors including their socio-economic background as well as local government policies and priorities. Finally, we show that participants balanced desires for independence with more collective, interdependent, strategies for coping with impacts of severe weather.

Drawing these findings together with theoretical contributions from CDS and disaster research, we make three central arguments to help guide future crisis informatics and risk communications research in this area. First, we argue that individual experience of severe weather is produced through context, or the practices that draw together the broader network of social relations, environmental conditions, and the built environment [22]. Using Garland-Thomson's theory of the relations of "misfitting [27]", we suggest that attention to "fit" between bodies and context may make long-standing desires for risk communications tailored to various needs and abilities significantly more tractable. Then we integrate theories of interdependence and disability, as presented by Bennett et al. [4], Hamraie [35], and others [44, 84], with HCI work in the area of public design [17, 47, 48] to suggest risk communication strategies that leverage and contribute to collective forms of resilience and recognition of the expertise of disability communities. Finally, we show that the varied and diverse forms of uncertainty experience by PwVI during severe weather extend well beyond those typically considered by risk communication research. This reframing decenters the field's traditional emphasis on uncertainties related to weather forecast towards potentially more productive agenda aimed at reckoning with social and infrastructural uncertainties produced during storms.

2 Related Work

2.1 Severe Weather Risk Communication

Weather risk communication is an interdisciplinary field of research and practice that concerns the communication of information about weather-related hazards before, during, and after such events [69, 78]. Such risk messaging may concern the communication of immediate threats to provide actionable guidance in real-time or long-term risks to encourage disaster preparation and mitigation efforts, although both may save lives [78]. Research in this field draws on both qualitative and quantitative methods to understand how individuals make risk-related decisions and to develop effective means of communicating complex weather information to the intended audience. Most often, risk communication is conducted in partnership with meteorologists and other experts in government or research institutions. The objective of these collaborations is to convey information about forecasted weather conditions to at-risk communities and response organizations in order to support decisions about safety and emergency preparedness. The effectiveness of weather risk communication is often determined by its ability to support informed decision-making and protective actions [16]. Effective risk communication also involves anticipating and addressing the specific needs, vulnerabilities, and cultural beliefs of the target audience [6, 52, 74, 77]. The creation of successful risk communication campaigns is thus often thought to be predicated on the participation and feedback from target audiences [18].

In recent years, risk communication has emerged as a specific topic of interest for crisis informatics and social computing researchers. This research has highlighted the limitations of official risk communication from government agencies and the strategies users employ to find reliable information [33, 69]. Importantly, this research has found that uncertainty may result in complex and speculative perceptions of risk [34] during crises, although emphasizing uncertainty or alternative outcomes in visual aids may support improved decision-making on the part of the messages' audience [29, 34]. Prior work has also noted the limitations of so-called "broadcast models" of risk communication, wherein authoritative

channels distribute a singular primary stream of communications to all audiences [8]. In response, demands for increased personalization of risk messages are common, but efforts to accomplish this goal face recurring hurdles ranging from technological feasibility to traditional reliance on intermediaries such as local news or emergency management to relay information within local contexts [56, 78].

Despite the disproportionate impact hazards may have on disabled communities, there has been surprisingly little research on the specific needs, challenges, and contexts of use they may have with regards to risk communication. Moreover, a recent review found that the majority of what does exist has focused on disabilities related to mobility, with sensory disabilities relatively ignored [60]. One study of the 2017 Hurricane Season in Puerto Rico did find that due to recurring power outages and intermittent internet connectivity, individuals whose assistive tech required electricity or mobile data were disproportionately affected [54]. Partially as a result of the lack of research in the area, contemporary risk communication products and practices are frequently inaccessible or unusable for a wide range of abilities and informational needs [78]. For example, weather maps, radar imagery, and visual graphics are standard components of risk communication, and frequently do not include sufficient accompanying text descriptions to adequately convey their meanings [76]. While very real opportunities exist to make these tools accessible to a broader audience, we argue in the next section that the mandate for an HCI approach to weather risk communication informed by critical disability studies has a much broader mandate.

2.2 Severe Weather Events, Emergency Preparedness and Disability Studies

The information needs of people with sensory disabilities have gone largely unaddressed by current emergency management practices, a failing which may result in dangerous or even life-threatening situations for this group. Often PwVI are unable to respond to emergency alerts, early warning protocols, and immediate hazards which thus poses a threat to their safety. Instead, people with sensory disabilities must often rely on friends, family, caregivers, private/public disability agencies, and local emergency services during weather emergencies [15]. Despite the increased vulnerability this group may experience, it can be difficult for some individuals to receive special care as they need to register with their local agencies – a process that may be challenging due to lack of accessible technology [38]. Such challenges are compounded by a lack of adequate consideration of PwVI by many emergency management frameworks. The relevant framework in the Canada focuses on the specific barriers experienced by some marginalized groups, including women and Indigenous peoples, during disasters but does not address individuals with sensory disabilities [70, 71]. There is a further complexity in terms of intersectionality of exclusions, as disabilities intersect with other forms of marginalization such as economic poverty, gender, or geographical exclusion [63, 64]. However, these disproportionate impacts are not simply a consequence of individual physiology. Critical perspectives in disaster studies have long emphasized that vulnerability is socially produced. In this view, disasters reflect ongoing structural conditions rather than natural events acting upon inert social systems [36, 89]. Accordingly, HCI scholars have also called for crisis informatics research to attend to the political and structural dimensions of disaster as a means to reorient the priorities of research and design in this domain [81].

These arguments align with critical research in disability studies which finds disability itself is produced through interactions between bodies and environments [3, 42]. Scholarly approaches to disability have evolved over time and across research contexts, but critical disability studies has largely turned away from individual models of disability, which focused on impairments as a problem to be solved on an individual basis, towards models that emphasize the structural production of disability [12, 28]. In recent years, critical disability scholars have further drawn attention to the situated material realities of impairment – embodied experiences where the impairments are shaped and experienced by the physical environment and specific social, cultural and historical contexts [26, 58, 59]. The concept of misfit/misfitting [27], which we explore further in 5.1, complements this by defining disability as a relational and material encounter between bodies and the environment. Rosemarie Garland-Thompson [27] define fitting and misfitting to "denote an encounter in which two things come together in either harmony or disjunction," and when context shifts so does the fit. In this view, the "discrepancy between body and world, between that which is expected and that which is, produces fits and misfits," and it helps us situate injustice or discrimination in the materiality of the world.

In this paper we weave insights from HCI, disaster research, and critical disability studies together to consider some initial pathways by which crisis informatics might approach disability and severe weather risk communications. There is significant prior work in accessibility focused on relevant topics such as evaluating and improving assistive technologies to support individual navigation and wayfinding [2, 43, 87, 88]. While much of this is clearly important, critical disability studies scholarship has long argued that approaches which locate remedy primarily in individual tool capabilities draw attention away from necessary foundational examinations of the relations between bodies, technologies, infrastructure, and social systems that produce disabling conditions [42]. In a similar vein, Bennett et al. [4] have written that traditional assistive technology research too often "promotes the idea of complete self-reliance as the ultimate goal whilst denigrating or ignoring the collaborative work done between people with disabilities." Drawing on Dourish's foundational arguments for the contributions of interpretive qualitative research as necessary interventions towards reconfiguring the terrain of design [21], rather than offering solutions to problems as already construed, and especially given the paucity of research on risk communication for people with visual impairments (PwVI), this work seeks instead to provide evidence-driven and theoretically sound directions for crisis informatics research into risk communications that take seriously the structural production of both disability and disaster.

3 Methods

3.1 Study Overview

This study is part of a multi-year research program into crisis informatics and risk communication by an interdisciplinary team of HCI

and disaster research scholars. As part of the broader study, we also collaborated with emergency managers and risk communicators from local and federal government and several local organizations serving PwWI and other vulnerabilized communities. For the part of the project described in this paper, we chose to focus on PwVI because the needs of this audience had been previously identified in academic literature, including our own past studies [78], as critically under-examined. Additionally, several members of the research team have prior academic and professional experience with social service organizations that work with PwVI and were thus well-positioned to collaborate with them and engage with research participants. We use the term PwVI advisedly and in accordance with our collaborators because at this stage of the research, we sought to develop an overarching understanding of what critical perspectives in HCI and crisis informatics might contribute to the broader problem space of improving the accessibility of severe weather risk communications.

3.2 Participant Recruitment

Participants were recruited on behalf of the research team by two community organizations that serve PwVI in the Greater Toronto Area via email outreach to their networks. Seventeen participants (9 male, 7 female, 1 non-disclosed) were interviewed. Participants ranged in age from mid-20s to 72 years. Roughly half lived in urban areas, with the remaining in the suburbs. Nine participants were currently totally blind with no functional vision, while five had low vision with some remaining sight. Regarding sight loss, nine participants were totally blind with no functional vision, while the remaining had low vision with some sight. Onset varied: seven had congenital conditions present from birth, while seven acquired sight loss later in life. Among those with congenital conditions, several experienced progressive vision loss over time, having been born with partial sight that later deteriorated. Participants used white canes, guide dogs, or relied primarily on door-to-door transit services for mobility. Nearly all participants used iPhones with VoiceOver as their primary mobile device. Most self-identified as proficient with technology, while three described themselves as beginners. Employment status varied: six worked full-time, three were retired, two engaged in contract or research work, and others were students, unemployed. Educational backgrounds ranged from post-secondary to doctoral level, with four participants holding graduate degrees. Five participants were recent immigrants to Canada from Europe or South Asia. As we will argue, designing effective risk communication tools for PwVI requires accounting for these varied circumstances. For the purposes of this specific study however, we sought to develop a set of conceptual or theoretical arguments that could support future research in this general area, so we do not report these details except as needed for clarity.

3.3 Data Collection and Analysis

Interviews were conducted online via Zoom by three members of the research team. The questions spanned eight general categories – personal context, weather and severe weather, past experience with severe weather events, protective actions and information seeking, community support, technology, risk communication issued by the government, and other – to understand how PwVI prepared for severe weather events, including the information and technology they relied on. Participants were sent the interview questions in advance. Verbal consent was obtained at the start of the interviews, which were audio or video recorded. Following the completion of 11 interviews, the research team discussed and reevaluated the interview questions based on preliminary findings. From this discussion, the general categories were unchanged, although the interview questions were amended to focus on participant stories as they offered the most comprehensive account of our participants' lived experiences during weather and severe weather events. Interviews were scheduled to last between 45 - 60 minutes, although in practice they ranged from 44 - 84 minutes. No personally identifiable information was included in the interview recordings The interview data was initially transcribed using Otter.ai. To finalize the transcripts, a member of the research team who conducted a majority of the interviews verified and corrected the transcripts during the familiarization phase of data analysis. Any time the researcher came across questionable or unclear text that obscured the meaning, or identified potential quotes for use in the paper, they consulted the audio and updated the transcripts as necessary. Transcripts were primarily edited to correct for unclear or ambiguous text, and not for disfluencies or punctuation. All data collection and analysis processes were approved by our university ethics review.

The research team engaged in an inductive approach to reflexive thematic analysis (RTA) [11] where the researcher's interpretation of the data is the primary source for developing codes and themes during the analysis process. Given the relative paucity of research at the intersection of crisis informatics, risk communication, and disability justice and the resulting exploratory nature of this project, our team determined that an inductive approach to drawing theoretical and conceptual insights from rich data about participant experience was most appropriate. As a starting point, each member of the research team reviewed five transcripts, where each transcript was distributed so that it would be examined by at least two reviewers. From this initial review, each member of the research team then proposed a set of qualitative codes they thought represented their reading of the data. The team also began discussing possible themes that their codes could support. To develop a set of interim codes, the first author compiled the list of qualitative codes developed by the entire research team and organized them into general categories. This author then re-coded the entire data set with this set of codes, and suggested some preliminary themes based on this data. The research team then further refined both the set of codes and proposed themes through iterative rounds of discussion, analytical writing, and engagement with the transcripts.

In reflexive thematic analysis, researcher's own knowledge, experience, and background are assets to data analysis, allowing for the generation of novel insights and arguments. Our research team consists of graduate students and faculty from the fields of HCI, information science, and disaster studies. Though we do not possess visual impairments, several members of the team have significant prior experience conducting research into accessibility or information systems related to disaster. We live and work in a major urban area in North America. As a result of both our physical location and our recruitment strategy, this study and our resulting contributions may exhibit some degree of urban bias, and be less attuned to the specific situations of other areas. We hope that future work in this

nascent problem space can contribute to a broader understanding of the challenges and design opportunities that exist at the nexus of crisis informatics, risk communication, and critical disability studies.

4 Results

We draw on our interview data and our experience as scholars in crisis informatics, disability studies, and risk communications to guide future design research in this space. Following standard practice in RTA, we include interview quotes to provide readers with additional details and nuance that may help illustrate particular facets of our arguments [11]. As such, we do rely on these quotes as evidence for the validity of our data analysis process or claim that they are necessarily reflective of all participants' experiences or perspectives [11]. We also stress that individuals with different forms of visual impairments may be uniquely or differentially effected by severe weather in ways that will also differ from those with other forms of disability. However, the arguments we make below are broadly relevant to improving future HCI research and design in risk communication with PwVI, and, as is common in accessibility research, may be beneficial for informing work with other audiences as well.

4.1 The Impacts of Severe Weather on Navigation and Mobility

4.1.1 Sensory Disruption Challenges Mobility and Technology Use. Sever weather disrupts the senses in ways that challenge critical navigation and mobility activities during crises. Our interviewees recounted the importance of triangulation between multiple sensory pathways – such as the texture of the ground and sound – as part of their everyday wayfinding, with several noting that these senses improved as their vision deteriorated. In particular, hearing was frequently highlighted as a resource for navigation, with participants mentioning that they used sounds including traffic and the wind to orient themselves throughout their journeys. Other senses, such as partial vision and smell, were cited, albeit less frequently, to help them navigate and prepare for severe weather events. For example, smell was used by interviewees both in anticipation of the weather event: "there's a kind of like, a certain smell in the air and I can tell us it's not all the time, but I can tell if it's gonna rain if there's a certain smell," or for ongoing preparation, such as detecting gas during storms. Given participants' reliance on these senses, weather was challenging for this group when features of the weather event and/or the interaction between the weather event and the built environment disrupted the typical use of their senses.

Chief amongst participants' concerns with regards to severe weather's impacts on their senses were the effects on the terrain they navigated. Precipitation such as snow and ice changes the texture of the ground which made the use of participants' limbs or assistive devices such as canes for wayfinding difficult. For example, participants mentioned that they could not differentiate between the sidewalk, grass, or the road when snow accumulated on a given path. For another participant, their hands were "like my eyes", and the use of gloves to protect them from outdoor falls rendered their hands inoperable. In addition to changing the terrain, extreme weather events also resulted in the development of physical barriers in the street. For example, the accumulation of snow could result in snowbanks which obstructed sidewalks and could be disorientating for white-cane users. Similarly, fallen debris, such as trees, could be hazardous to participants who could not use sight to detect them.

The use of hearing as a navigational aid was also disrupted by severe weatheg as it could interfere with typical sounds such as traffic, and leave people disoriented. In the case of snow, several respondents on the sense of disorientation as a the result of the muffling of sounds. Wind was similarly cited as overwhelming other sounds, with one participant commenting on its ability to change their perception of time, "If it's too windy, walking even for five minutes seems like 15 minutes." In contrast, rain was described as magnifying sounds with one interviewee explaining that "when it's raining the noise of the rain on yourself and also like on the road, like all the vehicles going on it's it's much much louder". This could cause respondents to lose their way as they had difficulty identifying both if cars were in motion or idle and their relative positioning to vehicles. Importantly, these sensory disruptions compounded during severe weather. Participants described simultaneously navigating wind that distorted traffic sounds, boots that eliminated tactile feedback, hoods that blocked their hearing, and snow that obscured familiar landmarks. Ultimately, this contributed to a general sense of unsafety during such weather events for participants resulting in limited or more complicated mobility options.

4.1.2 Challenges to everyday technology and information seeking practices. Inclement weather also hindered interviewees' routine practices of technology used to support mobility (see Table 1 in the Appendix for a list of technology mentioned by PwVI in our study). On a day-to-day basis, participants used an ecology of apps to support their regular navigation, including mapping apps, visually interpretive assistants, and AI assistants. Mapping apps, such as Google and Apple Maps, were primarily used to plan routes in advance and were often supplemented with visually interpretive (e.g., BeMyEyes or Aira) and AI assistants (e.g., SeeingAI) during navigation. Despite the importance of these technologies in supporting navigation and mobility, PwVI often avoided using them during inclement weather. In addition to concerns about rain or snow damaging their phones, holding devices in such conditions could be uncomfortable and potentially disrupt their sensory awareness. As a result, PwVI often had to forgo the use of this technology while in the midst of severe weather events, instead relying on alternative strategies discussed in Section 4.3 below.

Given the physical and spatial disorientation caused by severe weather events, respondents noted the importance of timely information in their safety-related planning. Official information such as weather alerts and warnings were often cited by interviewees as being particularly helpful in preparing for severe weather events by allowing them to schedule accordingly. For example, participants noted that they would plan their grocery shopping or work responsibilities around severe weather or complete the relevant safety-related tasks in the lead-up to the event. In light of the uncertainties surrounding severe weather and its impacts, and the significance of this information for advanced planning, flexibility was an important facet of people's severe weather preparations:

> "the weather changes... So you can make all the plans you want, you still have to make last minute arrangements if things change. So it's nice to have as much notice as you can get, but it doesn't always work that way. So you have to accommodate, you know, last minute changes."

As a result of the weather's unpredictability, several participants mentioned prioritized obtaining information to with enough lead-time to anticipate and plan, rather than waiting until closer to the potential event for more precise or accurate forecasts. To this end, they described used multiple devices and information sources to develop a comprehensive understanding of the situation. One participant who previously taught accessible technology and regularly uses multiple weather apps, described significant discrepancies between sources: "One said we were going to have freezing rain from nine till like 11. And the other one said it was going to be freezing rain from nine to like three, which is quite a big difference if you're deciding when you might want to go out." In other examples, valuable information about topics such as snow accumulation or sidewalk clearing would be inconsistently reported across different sources. These inconsistencies complicated the planning that participants relied on to navigate severe weather safely. Reliance on multiple apps as well as different devices such as televisions, radios, smartphones, home assistants, and laptops, was also partly driven by the inaccessibility and limitations of certain sources. For example, television broadcasts often depend heavily on onscreen graphics, prompting participants to seek alternative sources for the same information.

The accumulation of environmental challenges, technology limitations, and information gaps created significant cognitive burden during severe weather. One participant described depending heavily on rideshare during cold seasons because "I just feel like I don't have time to fumble and bumble and try find my way and it's just so much going on." Another compared using multiple navigation apps while moving to texting while driving, noting "I'm listening to cars, I'm giving direction to my dog. I don't want to have a lot yammering in my ears." To manage the tension between needing technological support and maintaining sensory awareness, some participants adopted specialized hardware solutions such as bone conduction headphones or Bluetooth-enabled glasses that deliver audio information while keeping ears open to environmental sounds. These adaptations suggest that technology interfaces adding cognitive load—even when providing useful information—may be counterproductive during severe weather when attentional resources are already strained by compounding sensory disruptions.

4.2 Social and Political Determinants of Weather's Impacts

4.2.1 Socioeconomic Status as Shaping of Severe Weather Experiences. As with many aspects of disaster, the impacts of severe weather events were mitigated by the complex, intersectional features of our interviewees' identities, or subject positions. In particular, our participants varied in their employment status and income, factors which, for many, influenced the technology and resources they could use on a day-to-day basis and their ability to respond or adapt to severe weather events. For example, a significant distinction emerged between paid human assistance services such as IRA, which employs trained agents and free volunteer-based services, such as Be My Eyes. Participants who could afford IRA subscriptions described benefits including agents trained specifically in working with people who are blind, professional vetting that addressed security concerns, and capabilities like computer screen sharing for complex tasks. As one participant noted, "With IRA, first of all, it's paid individuals, and they're trained. So they actually know how to interact with people who are blind or low vision." In contrast, volunteer-based services, while valuable and more widely accessible, were thought to offer less predictable quality. Related, the use of car services, such as Uber, during weather and severe weather events, was common although these were either paid for by their employer or the participants incurred the costs out-of-pocket which, during "surge" pricing, proved to be costly. During severe weather events, when reliable assistance may be most critical, this cost-based distinction in service quality represents another dimension of inequity in participants' access to support resources.

A straightforward economic challenge faced by participants stems from the fact the apps and services that support mobility during severe weather universally require mobile data connectivity, which for many represented a cost barrier. One participant who works in advocacy with the sight loss community observed: "Data is very expensive... in our community, we do need quite a bit of data in order to utilize our phones and our apps the way we need to." She noted encountering this barrier repeatedly in her professional work: 'When I say to people, "have you tried this app?" they're like, "I can't afford data" or "I have data, I just can't use this much of it."' The inability to use most navigation apps offline compounds this challenge—participants without data access lose technological support precisely in the unfamiliar or emergency situations where it would be most valuable. While some participants reported having generous data plans, this likely reflects their particular economic circumstances rather than the broader community of PwVI, many of whom face employment barriers and disability-related expenses that constrain their technology access. Employment status and labor relations also shaped individuals' experience of severe weather. For example, prior to the COVID-19 pandemic which normalized working from home, one participant noted multiple instances where employers refused their request to do so and inhibited their flexibility to respond to severe weather events:

> "I went to meet them on the Monday and my job was starting on the Tuesday, (anonymized). That morning, that was going to be a big, big snowstorm. And I said to my employer, because it's going to be a snowstorm in the morning and she said "No, you're working you show up here at 9:00 or 8:30 or 8:30." So I had to call this, I knew there was going to be a weather thing and the CNIB had an orientation mobility instructor, the job was in (anonymized)...So then we had to walk to the employer through the snow like that. Going out in a snowstorm and they don't care if there's a storm...I had to go. And I'm so so glad the pandemic changed

> that, now you can work from home. You don't have to risk your life to go out in bad weather."

Indeed, many participants noted that the increased acceptance of working from home allowed them flexibility to better navigate weather and severe weather, thus mitigating some of the negative consequences of these events by helping to offset some of these challenges. However, not all jobs or employers allow remote work, or are willing to make exceptions during emergencies, meaning that people, in particular lower-wage workers, cannot rely on these forms of accommodation.

4.2.2 Local Government Policies and Communication Practices as Co-Determinants of Accessible Public Spaces. By and large, participants recognized that some of the challenges they experienced during severe weather events were the result of the current institutional and social contexts they lived in, noting that municipal emergency preparedness planning frequently failed to account for their needs. One participant recounted meeting with city emergency officials who advised, "Just get a sighted person to come and help you." She responded, "That is no answer. Because not everyone can, or the sighted people might not be able to get through to where you are." Evacuation planning presented additional concerns: "When there's forest fires, I noticed that, oh, we're all driving out. And I was like, but I can't drive out." Participants advocated for emergency shelters accessible by transit or walking in multiple neighborhoods, and for disability-specific emergency alerts that acknowledge the distinct information needs of people with visual and other impairments. One participant noted the absence of "anything in particular" for people with disabilities in emergency communications, expressing desire for systems that would allow isolated individuals to signal for help, "Maybe a way for you to say, here I am, help me."

Respondents noted that their concerns about navigating and wayfinding during snowfalls, the predominant form of severe weather in the region, were exacerbated by improper or delayed snow clearing practices on the part of the relevant municipal government. Indeed, the lack of predictability of these institutional practices or communication about current or planned clearing were a major challenge for participants. Some interviewees felt that as much attention is paid to road clearing in the cities they resided in, but little attention is paid to clearing the sidewalks. One participant told us, "As a disabled individual, the city is not clearing the sidewalks. And when they clear the roads, they create snow drifts... they push [snow] up against the sidewalk and that makes the sidewalk inaccessible." Road-focused clearing thus actively created barriers for pedestrians even as it improved conditions for motorists. Participants also observed inconsistent sidewalk clearing across neighborhoods, with some reporting differences on opposite sides of the same street. One participant reframed the challenge: "The problem is not the weather. It's that they don't clear the sidewalks." This perspective locates the cause of mobility barriers not in weather events themselves but in policy choices about infrastructure maintenance priorities.

In addition to the ways in which improper or unpredictable clearing impacted mobility, participants noted that the current state of public transit exacerbated their challenges. Interviewees reported that the public transit was often unreliable during varied and severe weather events. A resident of a major city in the region explained, "The bus route has changed. Not stopping at this stop because... when we had severe snowstorm, they were only stopping at the main stops, they were not stopping at some stops, because the snow was a lot. It wasn't safe to let people off there. So that's something good [to know], because then you can plan, right?" When asked how she found out about this, she replied: "You just get on a bus... You don't know." At the same time, the specialized transit service that is available for persons with disabilities in the region required advanced scheduling and only provided occasional "same-day" trips. Given the unpredictability of weather and severe weather events, the unreliability and lack of information about the status of transit infrastructure hindered both respondents' mobility and capacity to plan ahead.

4.3 Collective Action, Choice, and Agency as Important Contributors of Safety

4.3.1 Interdependence and Severe Weather Events. In addition to relying on formal institutions—such as government forecasts, the country's official alert system, and news agencies—for information about severe weather, participants turned to informal social ties and collective, cooperative systems. This reliance was partly a response to the perceived failings of official channels, which participants described as "reasonably accessible" but often sensationalized or lacking localized information relevant to their decision-making. For some respondents, family members and partners were active collaborators in weather monitoring and planning. One respondent, a retiree in his sixties who lives alone, described daily weather discussions with his girlfriend: "We're pretty close. And we talk all day every day about the weather. Because we live in separate accommodations." This ongoing communication allowed both partners to track conditions and coordinate their activities. For participants who lived with partners, support was even more direct. Another participant, a 72-year-old retiree who is learning to use assistive technology following recent vision loss, stated simply: "My greatest technology is actually my wife. That's not really a joke, that really is serious. I am very dependent on her for that."

In addition to family, participants described information sharing within the visually impaired community as essential to their weather preparedness. As one explained: "We talk a lot about weather and if something is happening or something happened the day before or something is going to be happening. It's something we talk about, we let other people know because again, a lot of times it's harder for us to sometimes find that information. So we will share that." This was particularly valuable for participants who were immigrants to Canada and lacked prior knowledge of local weather patterns or how to prepare for severe conditions. Another described informal networks among guide dog users: "We all have sort of groups that we're part of to some extent. So sometimes it's word of mouth... somebody might say, you know, it's not a good day to take a guide dog out today, it was just too cold." Non-profit organizations played an important role in fostering interdependence. Participants noted that these organizations adapted their community-building approaches to member preferences—using online gatherings alongside in-person meetings, and communicating via email in addition to less accessible social media platforms.

Interdependence in these networks was frequently described as reciprocal. Participants both received and provided support within their networks. Several described actively checking on community members before and after severe weather events, "Since I'm very involved in community organization for people with disabilities support group, informal and semi-formal groups. People also call to find out what they can, where they can find help in terms of getting some groceries and all that. Before the snow stops, before the severe weather, then we check with our network people and get that." Beyond weather-specific information, participants shared technical knowledge about accessibility workarounds. There ends up sometimes being workarounds that the blind community tell each other about—you know, like, "oh, well, if you slow down the speed of this, or you change that.'" A local association of visually impaired sailors provided particularly detailed weather information to its members, given the importance of conditions to their activities. Such community-specific channels supplemented—and often exceeded—official sources in relevance and utility.

4.3.2 From Interdependence to Independence. Despite the importance of interdependence, our participants nonetheless emphasized independence as a key value. In contrast to conceptions of independence that suggest people with disabilities should operate without support of others, Bennett et al. [4] frame the independence desired by people with disabilities as a freedom from coercive systems of dependence. To accomplish this, participants developed, or learned from others as described above, creative strategies to maintain independent navigation during severe weather. Some used their canes to find and follow indentations in snow left by previous pedestrians, while others tracked rumble strips when crossing roads. These techniques allowed navigation when technology was impractical and bystander assistance unavailable. Some participants developed remarkably innovative personal solutions. One described installing an electric doorbell on his house and carrying a remote: if he became disoriented during navigation, he would trigger the sound and use it to navigate back home. Another created a homemade weathervane with a clicking mechanism—a card inserted to click with each rotation—allowing him to count clicks and estimate wind speed without visual observation. Underlying these strategies was a broader self-conception of agency. One participant described this feeling directly:

> "You just don't sort of stay in your house and say, 'Oh, well, I got a visual impairment type of thing. And I'm just going to wait till the sun melts the snow.' It's not like that. We have to—we do everything the same, just as anyone else would do. And we take into consideration whatever has to be done."

The capacity to choose when to recruit others into their support networks was essential to participants' sense of independence. Participants frequently enlisted strangers and passersby into their support networks, particularly for "last mile" navigation when technology could only approximate their destination. However, participants had to negotiate the costs and benefits of requesting assistance. One noted the practical advantages: "It's a lot faster than having to use my phone and ask someone who doesn't know where things are going to get in and get things done as quick as possible. Oftentimes, having the help of a real person is better." Yet retaining agency was important—participants valued choosing when and from whom to request help rather than having assistance thrust upon them. One expressed frustration with well-meaning bystanders who interrupted their navigation: "When you're blind and people see you standing up, they go, 'Oh, are you okay? Are you okay?' You know, I'm just starting to get my bearings and making a decision what I want to do, but they just come and interrupt you." Training programs offered by community organizations taught independent living skills, including physical navigation and technology use, that expanded participants' options. This enabled them to make informed decisions about when bystander assistance was needed versus when they could navigate independently.

Rather than trusting technology uncritically, many participants developed detailed understandings of its limitations and how do mitigate them. Glendon, who has used an iPhone since 2011, described learning that GPS arrival announcements are consistently inaccurate, "when it says 'you have arrived at your destination,' I know I haven't arrived there yet. Because it's always about 10 meters out, which is up to 20 feet inaccurate... So I figured 10 meters is about 16 steps. So I'm thinking, okay, I'm gonna walk 16 more steps." Such strategies allowed them to use technology as a tool while retaining judgment about when additional support, whether through environmental cues or human assistance, was needed. Indeed, several participants expressed concern about over-reliance on technology and emphasized the importance of preserving non-technological navigation skills. One participant articulated this tension, saying:

> "I don't want to lose the skill set... that skill set is critical. Because what if the technology doesn't work for some reason? Or what if I'm reliant upon my phone, and the battery dies without me realizing? I don't have a problem being supported by the technology, but I don't want to become absolutely reliant upon it."

He went on to describe how he relied on his knowledge of local traffic patterns to reorient himself After becoming lost near his apartment during a severe weather event:

> "I live in a neighborhood where most of the streets are one-way. One of them is a four-lane street. So the traffic that goes down the four-lane street moves fast... So I had to get myself facing in the direction the traffic was going fast on the four-lane road. And so now I know that I'm facing east."

This environmental knowledge, accumulated over years of living in his neighborhood, provided a resource enabling him to recover from disorientation without external help.

5 Discussion

5.1 Designing for Fit: Attending to the Contexts That Shape Individual Experience of Weather

Our findings suggest a pressing need for crisis informatics and risk communication scholarship in HCI to develop design strategies that account for how context shapes individual and communities' embodied experiences of weather, and in particular how severe weather events can bring bodies and environments into what Garland-Thomson has described as relations of "misfitting" [27]. Drawing these arguments together with critical theories of

urban space and the disability justice literature [13, 35, 53, 82], we note that embodied experiences are not a given; rather, they are co-constituted by context, including social relations and the built environment, where they can be periodically reconfigured as "fits" or "misfits". Dourish has stressed that context itself is not static, but enacted in situated ways that require careful attention to local practices that produce it [22]. This focus in turn should be incorporated into work to design risk communications tools and strategies, which currently do not account for important aspects of context, a limitation that creates challenges for users and may even contribute to the production of misfit for PwVI and others.

For example, this work suggets that simply improving the accessibility of current risk communication products or developing new navigation technologies, assistive or otherwise, are unlikely to overcome snowbanks blocking curb cuts, crossing buttons buried under snow, or sidewalks being systematically de-prioritized in municipal clearing schedules as opposed to roads. Instead, attention towards the ways in which fit and misfit is produced during severe weather events suggests alternative research and design pathways. Risk communication tools should therefore not only convey weather information, but also anticipate and communicate where misfitting could occur. Despite the impact upon our participants, the status of pavements in storm-impacted areas, and the misfits these conditions create, is not often considered within the provenance of traditional risk communications, or included in design strategies that would start with the goal of improving accessibility of existing risk communication products. However, through attention to the specific contexts in with PwVI experience severe weather and the goal to support users in accomplishing fit (as best as possible), previously overlooked information such as which intersections may become impassable, which transit stops will be inaccessible, or which routes will require recruiting bystander assistance or other forms of support become of vital importance.

Risk communication could also encourage the adoption of the beneficial practices individuals, communities, or other actors could take that help achieve 'fit'. Our interviews highlighted that in the aftermath of snow storms, neighbors or others who cleared pavement *fit* spaces that allow our interview participants to move more easily. In the absence of these activities, severe weather produced misfits, that segregated impacted people, creating spaces of isolation that limit the amount of social support available. Severe weather risk messages in Canada pertaining to snow (see Figure 1) in the Appendix for an example alert) currently recommend caution while driving, and could be expanded to recommend actions such as sidewalk clearing. This simple example highlights a wider set of opportunities for the design of risk communication that anticipates variability in fit/misfit across bodies and environments, and recognizes the importance of social relations through which fit is enacted [5].

As a more in-depth example, prior work to develop the concept of "crip time" [42, 73] has highlighted the subjective experience of time, i.e. how different bodies have unique rhythms and needs. This is in contrast to a standard, linear notion of "normative time" which assumes that everyone experiences and manages time in the same way, and which governs current emergency management practices, employment conventions, and public services. Due in part to the misfit produced by contemporary infrastructures, our participants reported desiring greater temporal flexibility in the face of severe weather events. In describing their experiences preparing for and navigating severe weather events, for some, such flexibility might entail greater workplace accommodations, such as the option to work from home or to alter their work hours. In other cases, this could involve altering the scheduling requirements of public services, including the timing of when risk messages are distributed, but also in the availability of accessible transit services. In this way, "rather than bend disabled bodies and minds to meet the clock, crip time bends the clock to meet disabled bodies and minds [73]" to enable better fit.

The recommendation to design for fit reframes prior calls in crisis informatics and risk communication regarding the need to develop and disseminate specialized messages that are targeted to the specific needs of particular audiences [57, 78]. Such work has long demonstrated the limitations of the so-called "broadcast model", wherein authoritative channels distribute a singular primary stream of communications to all audiences, in reaching, for example, individuals whose primary language is not that of the risk communication, or newcomers unfamiliar with local settings. In response, demands for increased personalization of risk messages are common, but face hurdles ranging from technological feasibility, lack of sufficient design resources, and traditional reliance on intermediaries ranging from local news to emergency management to relay this information within the local context. We argue that contexualization of fit/misfit through attention to questions such as how different audiences will encounter environments during and after weather events, where are misfits likely to occur, and which collective practices can help in achieving fit makes the intended outcomes of targeted risk communication much more tractable. Following Dourish and the examples above, a design oriented towards the situated practices of context-production as they relate to fit/misfit is a necessary starting point for future work in this direction.

5.2 Infrastructuring Weather Publics

Within disability studies, community resilience is often framed through the principle of interdependence [4], bringing not just people, but technologies, organizations and the environment into the community network. For its part, crisis informatics was largely founded in response to the intervention of emerging technologies into people's longstanding and well-documented desires to seek and share information as well as other forms of support during disasters [65, 67, 85]. Collectivist efforts towards providing support during disaster, ranging from local and grassroots mutual aid organizers to global non-profit organizations have frequently developed innovative uses of technology to accomplish their goals, but are not generally considered as subjects of risk communication efforts [67]. The prevalence in our interviews of collective support strategies during severe weather, as well as the long history of mutual aid in disability communities [35], indicate that future design research should examine forms of risk communication oriented towards audiences as collectives, as well as account for the role that collectives play in distributing risk information amongst their members. Consistent with models of dialogic risk communication [18], it should also recognize the particular forms of expertise they

can marshall about their local environments as a resource to include in risk communications efforts.

The practices of infrastructuring, which Le Dantec and DiSalvo note are integral to the formation and maintenance of publics, offer a framework to understand the design implications for a more expansive vision of the potential benefits of dialogic risk communication. Infrastructuring, in these terms, involves an ongoing process of enhancing and strengthening connections to both social and material resources. Participatory design workshops, the development of weather "competency groups" [45], and other two-way conversations that bring together PwVI, their support networks, emergency managers, and weather forecasters during periods of calm weather may infrastructure the relationships and publics needed to build shared understandings of weather risk and effective mitigation plans. These activities could surface the pedestrian-specific knowledge our participants hold, including locally specific but highly consequential details raised during our interviews such as where crossing buttons become buried in snow, which routes remain passable, how long specific neighborhoods take to clear, while also helping risk communicators better understand the needs of the community. Consequently, when severe weather occurs, stronger social ties and a robust frame of reference for informational needs, capacities, and effective means of support would already be available. This could also help build trust in risk information, which is necessary for people to act on it and a recurring challenge in the field [6, 78].

In addition, design research should also explore how to support the community information practices through which weather publics already operate. Our interviews revealed extensive peer-to-peer information exchange, and future work could examine how risk communication systems might amplify rather than replace these existing channels. This could be accomplished through interventions aimed at easier sharing of alerts within support networks, providing mechanisms for reporting and accessing local conditions, or supporting the informal 'is it safe to go out today' exchanges that already shape many of our participants' decisions. Such an approach would be consistent with disability justice principles of collective access and interdependence [5, 84], which position disabled communities not as passive recipients of services but as experts in navigating inaccessible environments. Where appropriate, these efforts might also seek to include emergency managers, forecasters, or other sources of traditional weather expertise as additional resources in the network. While prior HCI research [87] has investigated the role of design practices in infrastructuring publics around disability justice, further organizing around weather emergencies may help build necessary alliances between this community and disaster experts to advocate for the structural changes necessary to address the forms of marginalization that produce both disability and disaster risk.

5.3 Reframing Uncertainty

Uncertainty, in its various forms, was a prevalent theme in our interviews and is a central concern in disaster studies [19, 86], crisis informatics research in risk communication [8, 78], and HCI more broadly [79, 80]. While much of the conversation in the field centers around reducing uncertainties by improving predictive capacity as well as improving the design of the information artifacts used to convey weather forecasts [7, 33], our research draws attention to people's unique and diverse embodied and affective experiences of severe weather, their perceptions of space and time, the challenges they encounter, and the creative solutions they develop in response. Such attention points toward more pressing, if less obvious, "modes of uncertainty" [79, 80] worth examining as part of efforts to improve the design risk communication strategies, information products, and technologies to support PwVI during disasters. The forms of uncertainty that people encounter as a result of severe weather are partly a consequence of the limited ability to predict and effectively communicate the exact characteristics and impacts of storms, but these are only part of the story.

First, consistent with prior work in crisis informatics [97], this study draws attention to the need for designers to specifically attend to the ways in which uncertainty is unevenly distributed across different populations. Our interviews surfaced generally lower risk tolerances for ice, snow, and other conditions that impact physical mobility, thresholds that broader risk communication strategies are not tuned to account for. These concerns reflect systematic differences in how weather conditions translate into risk for bodies that navigate the world through non-visual means. We also noted a persistent temporal misfitting between the schedules of forecasting, maintenance, transit and the time that PwVI may require to plan their mobility in advance, process information, and make decisions during emergencies, again highlighting the design tensions between forecaster priorities of accuracy and advanced warning. As one step towards designing risk communication tools that consider these disparate impacts, HCI designers and researchers might consider expanding upon prior research into the mobility skills and technology leveraged by PwVI during navigation [2, 43, 87, 88], to examine in greater detail the specific ways these resources are deployed during severe weather events. This research may inform the development of technologies such as navigational assistants to be more robust to the challenges presented by weather events, and would complement many of the technological solutions already prototyped and developed for this audience [30, 31, 72].

Another critical but often overlooked aspect of uncertainty in risk communications practice is how perceptions of uncertainty may differ depending on one's experiences [88]. For example, the emotional or affective experience of being uncertain may shape how people seek and evaluate information during emergencies [56]. Our participants echoed this sentiment, with many noting that situations surrounding mobility, planning, and preparedness led to additional stressors that normative risk messaging audiences may not experience. Research in risk communications has repeatedly found that emotional states impact how people perceive and respond to this messaging [50, 83], but this area of study has not yet accounted for disabilty concerns. Other work has looked into the role of risk information products in eliciting specific emotions [56] in order to guide certain protective decision-making behaviors, e.g. evacuations or sheltering. In HCI, emerging research into the affective experiences of environmental data [23, 24] may provide insights or methods into how to support PwVI manage the emotional experience of the uncertainties that arise during severe weather or complement previous risk communication research into strategies

to convey urgent information without causing unnecessary fear or stress to the audience [57].

Finally, we note that there are important uncertainties surrounding many issues, beyond the specific characteristics of severe weather that impact people's experience of these events. As important as uncertainties about the onset, duration, or intensity of weather events are to share with the public, our research demonstrates that are many other things to be uncertain about during a storm which may be as or more determinant. For example, our participants suggested that efforts to ensure PwVI have access to information about street and transit conditions, connections to reliable support networks, and guidance on how to obtain necessary supplies ranging from food to medicine or other personal items in the case of needing to shelter in place for a few days, may support individuals in coping with or mitigating the uncertainties that arise during storms. Attending to a broader set of uncertainties people experience during severe weather and the information systems that can help mitigate them may have the added benefit of drawing designers and researchers beyond the traditional attention of risk communication research and into productive connection with broader literature in HCI on community resilience [14, 20, 75].

6 Conclusion

Together, the arguments we have made in this paper contribute to an improved theoretical foundation and research agenda for future research and design at the intersection of HCI, critical disability studies, and severe weather risk communications. To our knowledge, this is both a new area of focus for all three research communities, and one where there is a significant opportunity to improve upon current knowledge and practice. A key limitation of our study, which we hope can be addressed through future work, is the focus on visual impairments over other forms of disability. Additionally, due to the recruitment methods we used, it is possible that our participants came from a particularly interdependent community. Participants were involved in community events and social organizations or had connections with each other. Other studies suggest that PwVI are more isolated than other groups and may not have as robust of an interdependent community [37]. Rather than perceiving this as an indication that our participants are not representative of the visually impaired community, we see our findings as offering an example of how interdependence is already an important asset during severe weather events, and as evidence for our arguments for additional research and design aimed at supporting risk communication that meets the needs of PwVI.

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