People Talk in Stories. Responders Talk in Data: A Framework for Temporal Sensemaking in Time- and Safety-critical Work

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Global crowdsourcing teams who conduct humanitarian response use temporal narratives as a sensemaking device when time is a critical element of the data story. In dynamic situations in which the flow of online information is rapid, fluid, and disordered, the process of how distributed teams construct a temporal narrative is not well understood nor well supported by information and communication technologies (ICTs). Here, we examine an intense need for temporal sensemaking: time- and safety-critical information work during the 2017 Hurricane Maria crisis response in Puerto Rico. Our analysis of semi-structured interviews reveals how members of a global digital humanitarian group, The Standby Task Force (SBTF), use a process of *triage, evaluation, negotiation,* and *synchronization* to construct collective temporal narratives in their high-tempo, distributed information work. Informed by these empirical insights, we reflect on the design implications for cloud-based, collaborative ICTs used in time- and safety-critical remote work.

CCS Concepts: • **Human-centered computing → Empirical studies in collaborative and social computing**; **Empirical studies in HCI**;

Additional Key Words and Phrases: crisis informatics; digital humanitarian; distributed work; sensemaking; sociotemporality; temporal coordination

ACM Reference Format:
Wendy Norris, Amy Voida, and Stephen Voida. 2022. People Talk in Stories. Responders Talk in Data: A Framework for Temporal Sensemaking in Time- and Safety-critical Work. *Proc. ACM Hum.-Comput. Interact.* 6, CSCW1, Article 108 (April 2022), 23 pages. https://doi.org/10.1145/3512955

1 INTRODUCTION

Advances in information and communication technologies (ICTs) have spurred people to come together online to collaborate, socialize, and share. Over the past decade, ICTs have also played a key role in the emergence of *digital humanitarians*—global networks of volunteers that provide information support to emergency responders during large-scale humanitarian crises caused by disasters, pandemics, and the mass displacement of people due to conflict or persecution [32]. These online teams appropriate [64] free, cloud-based ICT tools and social media to gather, curate, verify, and analyze public information about the crisis zone through this specialized form of crowdsourcing.

Until recently, these homebrew systems worked well enough [70]. However, with the frequency and intensity of natural hazards on the rise and an historic 82.4 million people forcibly displaced from their homes due to disasters, conflict, persecution, and climate change [68], the scope and scale of high-tempo, time- and safety-critical distributed information work has become quite complex.

One digital humanitarian volunteer described the dilemma this way:

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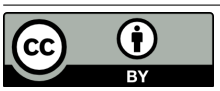

2573-0142/2022/4-ART108
https://doi.org/10.1145/3512955

> ***P1:*** *People talk in stories, but response teams talk in spreadsheets, charts, and maps. In order to extract actionable information from average citizens, the community-generated data has to be collected and processed in a standardized, structured, and organized way.*[1]

In this study, we describe an intense case [46] of temporal breakdown in information work in order to focus on both the visible and invisible ways that digital humanitarians constructed a "real-time" narrative of the devastating 2017 Hurricane Maria impact on Puerto Rico. We ask: *What sensemaking approaches do globally distributed digital humanitarian teams use in high-tempo, time- and safety-critical work? How do globally distributed teams collectively construct a temporal narrative from its sensemaking process to convey a coherent data story about the unfolding crisis?*

This research makes three contributions for the CSCW community:

- Insights drawn from nine semi-structured interviews that reveal a temporal sensemaking process of *triage*, *evaluation*, *negotiation*, and *synchronization* across the globally distributed team members;
- Creative speculation by the volunteers about how this four-stage temporal sensemaking process might be more effectively instantiated in work practice and the technologies that support the work; and
- Design implications for improving commonplace, cloud-based collaboration tools to better support high-tempo information crowdwork.

2 BACKGROUND: DIGITAL HUMANITARIAN WORK

2.1 Crisis Informatics

A *humanitarian crisis* is a large scale emergency caused by an environmental hazard, conflict, or public health threat that results in mass casualties, civil disruptions, property loss, and/or the sudden displacement of people from their homes [35, 50]. As mobile phones, social media, and messaging apps have gained a foothold across the world over the last 20 years, ICTs have become an important communication channel during crises that allow people to share information, document eyewitness reports, and even call out for help when public systems fail [32, 36]. During a single large-scale catastrophe, ICTs can contribute tens of millions of publicly-available data points.

The resulting deluge of data has given rise to *crisis informatics*, a subfield of information science, which uses human- and machine computation, sociotechnical systems, computer-supported cooperative work and social media (CSCW), and human-computer interaction (HCI) methods to improve information sharing about crisis risk, warning, response, and recovery [42].

As a new sub-discipline, the early empirical work in crisis informatics has necessarily centered on initial knowledge building and theoretical framing, e.g., describing distributed work practices during mass emergencies [9, 63], examining the role(s) of social media in constructing situational awareness for crisis response professionals and the public about conditions on the ground [24, 69], and identifying the particular challenges of data analysis in fluid, rapidly changing situations where time and safety are critical factors [10, 38].

Here, we build on this canonical literature by delving deeper into two long standing and interrelated gaps in crisis informatics research — how data sensemaking as online distributed collaborative work takes place and how sociotemporality influences that process [10, 43]. We use the following case to explore these gaps through the lens of temporal data and improvisational work practices to more clearly understand the phenomenon in detail and begin to identify potential interventions for process improvements.

[1] Quotations are presented verbatim with minor corrections for clarity and mid-quote shortening represented by [...].

2.2 Digital Humanitarianism

"Everyday analysts" [44] first mobilized at scale in reaction to the catastrophic 2010 Haiti earthquake which left an estimated 200,000 people dead, 300,000 injured and 5 million displaced. Using relatively new social media and other cloud-based tools, concerned people across the world formed ad hoc teams to collaboratively produce geospatial mapping, SMS shortcode analysis, and Creole language translation within hours of the massive 7.0-magnitude temblor [32, 57]. In the intervening 10 years, the field of crisis informatics, and particularly, these highly-networked digital humanitarian groups have developed deep expertise in crowdsourcing, crisis mapping, and information support during time- and safety-critical events [5, 9, 22, 25, 36, 45, 48, 58, 62, 63].

For this paper, we turn our focus to The Standby Task Force (SBTF)[2], a 24/7 rapid response information support organization with 2,100 volunteers from 106 countries. Since its founding in the aftermath of the Haiti earthquake, SBTF volunteers have been called into service by the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA), U.S. Federal Emergency Management Agency (FEMA), and other international NGOs.

In its work, SBTF manually collects, curates, verifies, and analyzes public information from indexed websites and social media platforms, particularly Facebook and Twitter, for relevant news about the crisis. Like many other volunteer-based nonprofit organizations, the team appropriates free, cloud-based ICTs to conduct its information work [53, 70], including Google Drive, Google Apps Office Suite and ArcGIS as information management and artifact production systems and the synchronous communication platform Slack for chat-based team coordination.

2.3 Positionality Statement

The first author has extensive experience with SBTF in two capacities as a: 1) volunteer coordinator of 15 activations[3], including Hurricane Maria, and 2) researcher conducting long-term empirical studies of the group since 2016.

2.4 Case: 2017 Hurricane Maria

Homes, businesses, and public works infrastructures on the Commonwealth of Puerto Rico were destroyed after a direct hit by Hurricane Maria on Sept. 20, 2017. The Category 4 superstorm made landfall on the small U.S. territory, just two weeks after Hurricane Irma had earlier caused widespread flooding and utility outages across the island. SBTF partnered with FEMA to collect, assess, and map public data on the real-time operational status of hospitals and healthcare facilities across Puerto Rico. The 72-hour rapid response activation was conducted between September 27–29, 2017. Within 36 hours, SBTF reported reliable information on 33 high-priority hospitals. By the end of the activation, SBTF produced verified status reports on 63 hospitals, or 93% of those on the island, as well as 44 other critical healthcare facilities, including nursing homes, dialysis clinics, blood banks, and morgues.

3 RELATED WORK

While humans are remarkably adept at unconsciously synchronizing our bodies, social lives, and work with the world around us, we still don't entirely understand the mechanisms that innately lead us to productive rhythms instead of utter chaos [65]. Of particular importance to the computer-supported cooperative work (CSCW) community, Thomas et al. claim:

[2]https://www.standbytaskforce.org

[3]SBTF uses the term *activation* to distinguish its virtual information support from on-the-ground emergency response deployment.

> *...the ways in which people conceive of and experience time are often at odds with the ways in which interactive systems represent and express temporal factors* [66, p. 3303].

The human side of this experience-representation disconnect breaks down into four component parts: *social constructions of time*, *distributed coordination*, *temporal sensemaking*, and *temporal narratives*.

3.1 Social Constructions of Time

For work and other social activities to productively unfold, people use different frameworks and metaphors to structure to time and ascribe meaning to it. One key structure in modern life is the *sociotemporal order* [74], which provides common systems, values, and norms to understand both "what time it is" and how to put that mutual temporal knowledge into social practice. Sociotemporal order is depicted by clocks, timestamps, time zones, live streams, calendars, and schedules that enable people to share the same notion of time and act on it in coordination [1, 2, 20, 39, 74]. However, even with these trusted artifacts, time still must be calibrated and then agreed to or *sociotemporal disorder* breakdowns may occur (c.f. [37]).

Establishing sociotemporal order within a team is difficult because social constructions of time are complex and may be influenced by multiple phenomena, including cross-cultural ideas about time [34], different temporal frames of reference to enact turn-taking and other shared interactions [26], time as an ephemeral quality [21], social rhythms of communities [59], an organization's temporal depth and how it orients itself toward the future [6], and the timescapes people use to contextualize time against socio-cultural and environmental concerns [2].

Here, Nowotny's exploration of pluritemporality [39] offers helpful clarity about how people interpret and make sense of different social constructions of time that may be experienced simultaneously. "Plural time" reveals both the hook to label the complexity of experiencing multiple forms of time and conceptualizes the representations necessary to form shared understandings of time that support temporal coordination.

3.2 Temporal & Distributed Coordination

Besides having a common agreement about telling the time, people also need to be able to act on their shared temporal knowledge in order to synchronize in *temporal coordination* across individuals [18, 31, 51]. The ubiquity of this shared sense of sociotemporality is evident in clocks embedded in mobile phones—which provide both precision as well as a single source of clock-time that influences how we socially align activities with one another [28]. These analog and digital *social constructions of time* allow people to establish rhythms, patterns, routines, and other types of ordered behavior necessary for coordination *in* time [33].

For distributed teams of remote global workers, establishing a common framework for clock-time is already quite challenging over time zones and diurnal phases, let alone creating organizational and communication structures to achieve *distributed temporal coordination* over both time *and* space [41].

As distributed teams make use of and appropriate sociotechnical systems, such as cloud-based collaborative ICTs, in novel ways to conduct their work, spatial and temporal coordination problems come into sharp relief [64]. One specific problem of these tools is that they largely reflect temporality as mechanized time. As one common example, free office suite platforms, like Google Docs, can denote the time-stamped revision history of a shared document but not the socially constructed experience *about* time, such as turn-taking that could help to avoid overwriting data entry during a flurry of activity.

The pace of work is also especially problematic for non-collocated teams engaged in 24/7 time- and safety-critical work conducted by digital humanitarians and other crisis responders from two perspectives. First, there is an unrealistic assumption of "real-time" responsiveness, or an always-on, immediacy of effort. Either that a large crowd of humans can computationally match machine processing or that automation, machine learning, and artificial intelligence are the next generation of digital humanitarians unencumbered by human notions of time. Taking a more critical data studies perspective, Hu [23] argues that real-time is simply a frame for thinking about events that are digitally mediated by time. The event becomes more "real" and meaningful with retrospective reflection—a thoughtful process not afforded in the hyper present. Second, high-tempo collaborations are driven by extreme urgency for situational awareness in the crisis zone. The need to quickly assess a high volume of data with little to no time or technical support for contemplation—a common refrain for attention in temporal design [49] and the "slow technology" agenda [40].

3.3 Temporal Sensemaking

While distributed coordination infers a need for sociotemporal agreement to allow work to productively unfold, much of this labor does not include a particular *collective mind* to produce uniquely time-critical information work, such as digital humanitarian crisis response, that exists both in-time and of-time.

The *"collective mind"* is a perspective that describes how individuals develop an understanding about their own contribution to group work [11] that extends prior theoretical work on sensemaking by Weick and Roberts: *collective mind* is established through a process of new member socialization, opportunities for conversation, and telling of organizational stories that are repeated, reinterpreted, and reinforced for newcomers and veterans alike [73].

Rather, these activities directly engage in *temporal sensemaking*, a complex cognitive and social process that integrates *common agreement* about a particular social construction of time, (e.g., past, present, and future) with *shared meaning* to create a retrospective sense of order through collective interpretations and explanations about ambiguous information [72, 73].

Dawson and Sykes [14] suggest that sensemaking is inextricably linked to temporality due to "a backward glance for retrospective explanation" and the act of "seek[ing] to reconstruct events from the past." However, during an unexpected crisis, time is not experienced as an entirely linear phenomenon. Waller and Uitdewilligen [71, p. 188] argue that in chaotic emergency scenarios, "sensemaking is of crucial importance for reducing confusion, guiding action, and preventing organizational disintegration." In other words, crisis information is revealed *over time* and not completely at the onset. The reality of this form of information flow curtails the team's sensemaking and thus its capacity to distribute their knowledge.

3.4 Temporal Narrative

Temporal narratives are often used as devices to help construct a sense of sociotemporal order. Boje describes *"organizations as collective storytelling systems* in which the performance of stories is a key part of members' sensemaking process and a means to allow them to supplant individual memories with institutional memory" [7, p. 106]. Expanding on this idea, Cunliffe et al. define *temporal narratives* as a series of collectively negotiated interpretations of an event over multiple points of view, multiple contexts, and multiple moments in time [13]. Here, Zerubavel's concept of sociotemporal order [75] provides some clarity about how temporal narratives are organized and the role they play in coordination work. This same sense of order and mutual agreement is also crucial for structuring a coherent narrative within a shared social context.

From the perspective of increasing social complexity in modern life, Cunliffe and Coupland argue that temporal narratives must also take into account real-time experiences [12, 13]. They argue that Weick's classic description of sensemaking as a linear, retrospective rationalization about *what just happened* is not as helpful in these instances. Instead, temporal sensemaking and the stories that flow from complex events are threads interwoven in time—responsive to the future and the present, as well as the past. To explore this notion further, we interrogate the experiences of people engaged in high-stakes, high-tempo, real-time collective sensemaking that requires stitching together a temporal throughline to understand what happened in the immediate aftermath of Hurricane Maria.

4 METHODS

To explore how temporal narratives are constructed and employed in distributed humanitarian organizations, we conducted a series of semi-structured interviews with 9 volunteers who participated in SBTF's coordinated response to the Hurricane Maria disaster in Puerto Rico. We analyzed the data inductively, focusing on uncovering high-level themes related to how the volunteers constructed and used temporal narratives in their distributed work and the suggested role of imagined future technologies in better supporting the work of the organization.

4.1 Participants & Recruitment

We identified 29 potential participants who were among the most active SBTF volunteers during the Hurricane Maria hospital status activation. We used SBTF's activation roster, which tracks volunteer sign-ups and contact information, to flag volunteers who contributed at least 3 entries to the data collection sheet to ensure that participants had substantive enough experience in the activation to describe their work practices and strategies for sensemaking.

Nine SBTF volunteers from Europe, North America, South America, and Southeast Asia initially responded to our interview requests. This subset of volunteers devoted substantial time to the 3-day activation (Mdn = 8 hours; range: 1-32 hours), according to self-reports collected by SBTF at the conclusion of the activation. Further, this volunteer pool also represented a mix of experienced hands including Core Team members, as well as those working on their very first activation. Participants were not compensated.

We continuously reviewed the interview data for novel insights and stopped recruiting participants once we reached theoretical saturation, e.g., repeated descriptions of work practices that yielded no new information when triangulated against other data sources such as Slack chat transcripts, hurricane data collected by the volunteers, multiple research team walk-throughs, etc. [15, 19]. Here, our goal was to identify and understand the various approaches that SBTF volunteers use to construct collective sensemaking about a humanitarian crisis unfolding over time. We determined that theoretical saturation was reached when the participants' used similar language to describe sensemaking processes, e.g., triage, and invoked the same examples from the activation to explain technical challenges to achieving collective meaning, e.g., algorithmic throttling of social media timelines that favor predictive engagement of the reader in lieu of a true chronology of messages by the poster(s). The intense nature of collaborative digital humanitarian work yielded rich descriptions of the processes by which the group collectively makes sense of a complex and unfolding situation.

4.2 Data Collection

The first author conducted all of the semi-structured interviews over Skype, Slack, or telephone, per the participants' preference. The median interview length was 108 minutes (SD = 33.3, range:

33–143 minutes). Each interview was audio recorded and transcribed for analysis. The interviews yielded 14.5 hours of in-depth discussions with SBTF leadership and volunteers.

The semi-structured interview protocol (see Appendix A) was developed iteratively by the research team—grounded in the first author's experience during the activation helping other volunteers make sense of temporally confusing information. The protocol was further improved following an initial semi-structured interview pilot study with two experienced Core Team members to assess the feasibility of the research, critically evaluate the interview questions, and identify potentially fruitful interview question themes that emerged organically from the conversations.

Each interview began with a grand tour question [61] about the volunteer's overall Hurricane Maria activation experience followed by a mini tour question about their information search approaches to discover the post-hurricane functional status of hospitals in Puerto Rico. Subsequent questions explored different information work practices during the hurricane activation, with specific questions tailored to the role and experience of the individual, but generally following a typical volunteer workflow, including how each volunteer:

- discerned time-related data/metadata,
- assessed the recency/timeliness/relevance of information,
- reconciled discrepancies and conflicts in the data, and
- managed time/tasks.

We prompted participants to offer perspectives about their own individual work practices, those of the group, and the cloud-based, collaborative tools used to collect and record the hospital data. The interviews concluded with a "magic wand" question to elicit concerns and speculative design ideas for improvements to current team work sensemaking practices and the technologies that they appropriate for this work.

Because abstract concepts, like temporal coordination, are quite challenging for people to discuss in direct terms, we designed the semi-structured interview protocol to flow alongside archival documents from the Hurricane Maria activation, which were used as a ticket-to-talk in the interviews [55]. The archival documents were posted to a password-protected website and accessible only by the participants. We also posted verbatim chat excerpts from the SBTF Slack channel and a copy of the SBTF Google Sheet used for data entry; both of which were specifically selected to highlight examples of common temporal sensemaking problems.

Grounding the interviews referentially in familiar documents helped to overcome the high level of abstraction about temporal sensemaking by prompting participants to have a dialogue with the document excerpts about specific time-related work practices and technologies [17] rather than attempt to interpret decisions about their past activities. Using archival documents as a ticket-to-talk also helped to re-immerse participants in the details of the digital humanitarian activation that occurred two years' previously, serving to bring past interactions into focus.

4.3 Data Analysis

We used a constant comparison method to iteratively and inductively analyze our data [8]. The first author conducted open coding of all transcripts and wrote memos in MaxQDA as each interview was completed. The suite of initial codes included temporal attributes, breakdowns, constraints, and workarounds. This step enabled the team to capture initial impressions, pattern match broader meta-themes, and conduct several rounds of affinity mapping from common language in the transcripts describing work practices, sensemaking approaches, and technical challenges. These methods were used to successively refine the codes throughout the analytical process.

In our weekly research team meetings, the first author conducted walk-throughs of each interview, contrasting work practice implications alongside the appropriated collaborative technologies

used by the SBTF volunteers during the Hurricane Maria activation. In addition, our meetings included a reflexive bracketing process [3, 67] to reflect on the analytic process and mitigate against preconceptions about the emerging insights due to the close relationship between SBTF and the first author who is a long-time SBTF volunteer. These reflexive provocations included collaboratively pre-writing interview questions and discussing interview responses to reveal inadvertent insider assumptions.

Once the first author completed and coded all 9 interviews and the research team completed its walk-throughs of all interviews, we used our team meetings to collaboratively identify themes reflecting similarities and differences across the transcripts [54, 56]. The initial suite of codes identified different facets—temporal attributes, breakdowns, constraints, and workarounds—that the SBTF volunteers encountered during the Hurricane Maria activation. These codes were further refined over subsequent open coding sessions by the team to reveal four sensemaking approaches that actively interrogate social constructions of time in digital humanitarian crisis response work.

5 FINDINGS

Distinct patterns of temporal sensemaking practices emerged through our thematic analysis. Here, we present four approaches to temporal sensemaking—*triaging, evaluating, negotiating, synchronizing*—that were prevalent in the descriptions of high-tempo, time- and safety-critical information crowd work. These sensemaking approaches are often used in combination to construct a temporal narrative from the disparate information collected by the SBTF volunteers as a way to convey shared understandings. These new insights extend prior CSCW research about how people talk about and navigate time at work and in their everyday lives [18, 27, 41].

5.1 Triaging Temporal Information

Information triage is "the process of sorting through (the possibly numerous) relevant materials, and organizing them to meet the needs of the task at hand. The term 'triage' seems particularly appropriate for this activity, since it is often time-constrained, and requires quick assessment based on insufficient knowledge" [30, p. 124].

All of the volunteers spoke at length about engaging in various triaging processes to order and prioritize the "fire hose" of information from social media and news reporting that was generated in the aftermath of the hurricane. Several volunteers specifically used the term "triage" to talk about their initial sensemaking work during the early, chaotic moments of the crisis response.

> ***P8: You have to triage a lot of sources to really get an idea of what could be happening.***

During temporal information triage, the volunteers described several influences—some that are in their control and others that are not—on their ability to prioritize and order large, cascading amounts of information from diverse sources. Each of these factors influence the ultimate value of the chronological narrative they are attempting to construct for responders.

For instance, the hurricane trajectory creates a temporal flow of data that impacts volunteers' ability to triage time-sensitive information.

> ***P1: I've noticed is that there is kind of an information life cycle during these emergencies*** *... There is the moment when the hurricane hits and that moment is a sort of blackout. You do not have much information coming because you do not know what to expect. And then after that, the hurricane has passed, you have this moment again where there's no new information coming. It may last a few hours or several days. It depends on the impact that the hurricane had because if there is no power, you might wait several days before you start to get some information. And then you start to have some sort of data*

> *flow here and there and then out of the blue you start to have an overload of information ...* ***The first hours there's nothing, there's nothing, there's nothing, then, out of the blue, there's everything.***

The inevitable information overflow demands a particular sensibility to the triaging process—acknowledging when an information search no longer serves the primary goal of crafting an actionable narrative for responders. This sense of when to stop chasing dead ends, let go, and move on to mine other information sources generates a fair amount of stress for SBTF volunteers due to the high-tempo pace of the triaging work and their strong desire to help vulnerable people while also contributing to a trustworthy report.

> ***P5: One of the other difficult things that we would run into is triage, of course.*** *And there's probably multiple senses of that term for just this sort of effort, but at what point do you say we can't verify this particular piece? Is there an easier one to work on that we may be able to deliver accurate work faster? Which sucks because ... it kind of feels like abandonment. Where could I point myself where I can actually get a result that's usable that maybe helps somebody sooner?*

Crisis information triage is often referred to as "finding a needle in a haystack" [16, 29]. Prior work in this domain has typically focused on the development of automated search and filtering tools and less on peer-to-peer crowdsourcing best practices for teams in which the overhead for developing and maintaining technical tools is high (c.f. [70]). The SBTF volunteers, however, voiced a need for more low-fidelity sensemaking support for crowdsourcing work informed by advanced technology:

> ***P1:*** *I think that one thing that we need to remember and that I really would like to change is to remember that* ***technology is not the solution for everything****. This is something that we always struggle a bit with our activators because they say, okay, you have kind of machine learning and then the machine will do everything.*

> ***P5:*** *There's got to be some good templates for just how to get familiar with what's on the Internet, what's useful, what's credible. How you can start making those on-the-fly judgment calls—which is what we were doing every second these deployments.* ***Honing your skills requires having, let's say, a good algorithm in your head that's properly calibrated to assess things****. It's on-the-fly analysis. Where do you go to get the info and then how you analyze it effectively?*

5.2 Evaluating Temporal Information

Once different hospital status materials are triaged, the volunteers set about to assess different temporal aspects of its informational value to contribute to the developing narrative. Despite the globally distributed nature of their work, each volunteer followed remarkably similar *temporal sensemaking evaluation* practices. All of the volunteers begin with a rapid assessment of the social media or news article timestamp to determine its recency. If the information was deemed sufficiently "fresh," then more scrutiny was placed on exploring other temporal cues and gauging the reliability of the source beyond the initial triaging process.

However, simply relying on timestamps was often a mixed bag for temporal sensemaking. The volunteers frequently mentioned the variation in timestamp formats across different online material, the nebulous information represented on updated news stories or edited social media posts, and the lack of timestamps on certain types of source material, like institutional press releases or hospital website announcements. Some used clever workarounds by comparing timestamps with other temporal references in the information.

> ***P6: I would definitely be looking at timestamps and trying to figure it out.*** *I dunno, I guess trying to make those judgments about the credibility of the people, whether they were there, whether it was firsthand information. Or whether it was something that they read or heard. If it's a news article, it can be from much earlier. So I don't know. I looked for ones that had specifics like where they said, 'I tried to go over there at 2:30 and [the hospital] was closed' or something like that.*

FEMA's request for real-time hospital status was often at odds with the representation of time displayed on the timestamp, which created an additional sensemaking burden:

> ***P5:*** *First of all,* ***you've got to make sure you understand what the timestamps mean on the sources****. For us, it was so important to nail down as close to real time as we could. But information gets stale so you can't always necessarily tell.*

The volunteers talked extensively about using different work-arounds to triangulate temporal and non-temporal information to enhance the sensemaking process, especially with respect to the credibility and reliability of when something was reported to have happened.

> ***P6: I would look for time-related details in the text of the tweet****, if they actually say what time it was in addition to just the timestamp on the tweet. But if they said, 'this morning as of,' if they actually mentioned a time, then I would find that much more reliable than seeing one where they gave details about an event but no time in the text.*

> ***P8: When you search for information this way, you triangulate many things at the same time****. If I found a tweet, what was this person tweeting before? Up to now? Is it a real person? Is it a bot? What does this person do? What are they interested in? What do they know about, right? How fresh is this information? Because in normal life, maybe a tweet two days ago could be very fresh for certain things, but working right now on this hurricane, a tweet from two days ago, is old. It's probably almost useless.*

Additionally, the challenge in using triangulation as an additional and more complex evaluative sensemaking layer is that triangulating is also beholden to the same rapid tempo of data collection as the triaging process, with a much heavier cognitive load necessary to construct a real-time account from the information at hand:

> ***P8:*** *I have two contradicting things.* ***I can find more information so I can tell you what really happened. But this is what I have****. Maybe you find something else and with both actions, then we can go into some place with some certainty. But, right now, I don't have it.*

5.3 Negotiating Breakdowns in Temporal Information

SBTF volunteers encountered numerous *breakdowns* that impacted their capacity to make sense of time-related information, ranging from large volumes of confusing material to triage and evaluate, to unreliable timestamps that frustrated their attempts to construct real-time narratives. Not only do these breakdowns need to be brokered on-the-fly by the volunteers, but different responses are required when the information is fundamentally incomplete or flawed, when it can be rendered *currently* actionable information with a bit of re-work, or where it is potentially useful *future* information that may reveal trends or predictive outliers based on the hurricane impact lifecycle—sometimes these perceived breakdowns aren't conflicts in the data as much as they are indicators of fundamental changes in the situation on-the-ground. As P5 remarked, ***"We get a big bucket of tea leaves to read!"***

For example, social media is a powerful source of information about individual stories of resilience and suffering, as well as the state of infrastructure and social conditions during a crisis. People

are often compelled to communicate and share information as a way to feel helpful or to process trauma [47]. However, the lack of internet access and/or electric service typical during a catastrophe contributed to lags in online reports—sometimes for quite lengthy periods of time—about the functional status of the hospitals following Hurricane Maria. These lags often meant less about the status of the hospitals, directly, than the surrounding infrastructure, although to a SBTF volunteer, the breakdown in information flow was often difficult to disambiguate, given their lack of physical proximity to or broader situational awareness about the state of the crisis environment.

SBTF volunteers also frequently encountered social media posts by unaffected family and friends that reference private text messages or phone calls from those within the crisis zone. While often rich in helpful local detail, these types of posts present their own temporal challenges because the information is often retrospective and shared with varying amounts of temporal delay. As a result, volunteers expressed skepticism about whether timestamps on social media posts accurately reflected current ground conditions:

> ***P3: So when somebody posts something, it may not correlate to when they experienced it.*** *And you know, this is part of the problem with what we do.*

Temporal breakdowns can also be quite complex, involving multiple pieces of conflicting data, timestamps, and equally reliable sources. Every volunteer recounted frequent instances of conflicting hospital status reports due to the chaotic situation on the ground. One negotiating tactic that a volunteer described was to re-engage with the source materials derived from the initial triage, evaluation, and triangulation processes, but re-contextualized against the current backdrop of the hurricane response trajectory. Here, the volunteer describes how they searched for the most-current hospital status by anticipating information breakdowns: areas where power, internet, and cellular service were still out would be less likely to post real-time accounts compared to sources in locations with proximity to restored services.

> ***P2:*** *And also, internet usage in an area where, you know, it's going to hit to see whether we would get information or we wouldn't get information from there. So if there's an area where the internet usage or social media usage is less than that, then you know most of the information is going to be posted to government sites or news portals and all that. And then you look at those sources of information. You see if some relative from another place is posting information about them, so it does make a big difference in the kind of information that you are looking out for.* ***You get that sense of where exactly you need to look.***

And, yet, unresolved temporal breakdowns can also be helpful for sensemaking purposes in challenging situations:

> ***P2:*** *You know,* ***sometimes even to have conflicting information is information.***

5.4 Synchronizing Temporality Across the Team

Once an information breakdown was identified, the volunteers described various ways that they worked to resolve the issue and *synchronize* their sensemaking process. One approach involved seeking out advice from more experienced hands in the Slack channel on how to reconcile contradictory information. Syncing up with other volunteers, especially Core Team members and Coordinators, also had the added benefit of hearing other interpretations about the data and how it might fit (or not) with the broader collective effort:

> ***P4:*** *... part of it is to work with the volunteers to* ***have them understand that both [contradictory data points] can be true****. And that's part of the problem: they don't have any sort of big-picture way to see it.*

This long-time volunteer described how they shared their own sensemaking process to guide another volunteer struggling with a complex temporal breakdown. Working together, P4 modeled a negotiating process that looped triaging, evaluating, and triangulating additional information, followed by another round of re-negotiating to either resolve the conflict or to verify the existence of parallel information:

> ***P4:*** *Now, let's see if we can figure out a story for this one. Does that give you enough intuition that you can do some more on your own that's not seat of the pants?* ***Really digging down ... [because] they are both possibly true.***

Constantly engaging and re-engaging with material was another strategy shared across multiple members of the SBTF team. The process of "tracing backward" to locate and share the original post helped sync up a collective understanding about the current information with respect to the "origin story":

> ***P4:*** *You also find times when things that are retweeted or shared from Facebook that can be quite old.* ***So, I'll also try and trace back to the original post or whatever it is to get a sense of when that is.*** *Then, also look at it chronologically, in the context of when and where the person who posted it pushed it out. It's not a linear thing. You have a hospital, you find something, you chase it down. Doesn't really work, doesn't make sense, doesn't tell me enough. Try again. Find a different source. Oh, that makes more sense. And that information is duplicated over here. Now, I go back to the original one. Does that make more sense?* ***It's so circular, iterative, and intuitive.***

Each of the approaches referenced above ultimately help the team stay engaged with one another — an important factor for advancing a shared chronological through-line that drives confidence in the collective sensemaking:

> ***P4:*** *I think because [the data] is so complex,* ***checking in with other people on a regular basis with the complicated ones really adds a whole other way of thinking about it.*** *That's really crucial. So talking to other people.*

> ***P4:*** *When [data entry errors are] egregious, we're very good during [the activation]. I think we're good at doing it in a humane way where we're not pointing somebody out. Somebody has a private conversation and you do it kindly. So, I think, for instance, we do a good job of making sure that people aren't breaking confidentiality or privacy issues.* ***'You know, if you did this, it would really make a difference. It will be a little bit harder, but look at how much better the data you would be collecting would look.'*** *But it's a hard thing to do in any circumstance.*

5.5 Crafting the Emergent Temporal Narrative

Cunliffe describes a temporal narrative as a series of collectively negotiated interpretations of an event over multiple points of view, multiple contexts, and multiple moments in time [13].

In the context of this study, the temporal narrative is constructed from synthesized information on-the-fly, of unknown provenance, in chaotic and uncertain conditions, and produced by a globally distributed team far from the crisis zone. In this way, the temporal narrative constructed by the volunteers is a synthesis from multiple points of view, contexts, and moments in time, resonant with Cunliffe's definition. The temporal narrative, as described by our participants, serves as both a function *of* SBTF's collective sensemaking and a product *for* sensemaking by the activation partner over time.

> ***P6:*** *You get a sense of the overall, bigger picture in that area without just looking at one post at a time. So kind of a way of* ***synthesizing the collective information*** *that's being posted about that particular point.*

The rapid assemblage of an actionable temporal narrative about the operating status of hospitals within a crisis zone highlights the tight integration necessary between the crowdsourcing process (*triage, evaluation, negotiation,* and *synchronization*) and the collaboration tools used (Slack, Google Sheets, ArcGIS, and social media platforms) in order to produce timely and trustworthy information.

> ***P9:*** *It's meant to be something that* ***can be done very rapidly before the others understand what is happening****. Puerto Rico is an example of a deep dive into analyzing what these messages are really about.*
>
> ***P5:*** *We're working to a deadline. I think with a lot of this, we in our position are always going to be* ***stuck with "good enough"*** *and playing the odds and making judgment calls, hoping that it's right.*
>
> ***P2:*** *So then if anything was not credible, then, what I would have done was till I actually find another source of information that can confirm that I would choose not to publish it,* ***to not give any false information, potentially false information there.***

Another key aspect of the emerging temporal narrative is crafting it to address the information sensemaking needs of the activation partner. Here, the volunteers reflect on recalibrating their temporal sensemaking approaches in order to not lose sight of the complexity and messiness of the data as a mirror of the chaotic ground situation.

> ***P4: I think keeping in mind the needs of the user****, is something that we do have to keep remembering that it's not whether or not we get caught up in a particular tragedy or particular story, but whether if we put ourselves in the shoes of the user of the data, will they want to know that?*
>
> ***P4:*** *Very often I'll say something to [volunteer name] that it doesn't really seem like it's adding much. I'm not quite sure which one to do. And [volunteer name] will take one look and say 'you'd make a different decision knowing both of those things than you would knowing only one of them. So both should be there.' He really brings it back to the user at the other side.* ***Being able to provide the kind of information the user at the other side is going to need and sometimes they need complexity.***
>
> ***P2:*** *I mean at the end of the day, despite all of these sheets, [the responders] ended up* ***looking at the map and seeing what kind of action to take.***

6 SPECULATIVE DESIGN ACTIVITY: VOLUNTEERS' IDEATIONS FOR BETTER SUPPORTING TEMPORAL SENSEMAKING APPROACHES

The work of SBTF is mediated (and often constrained) by the appropriated assemblages of free, off-the-shelf cloud-based collaboration tools they make use of. Two particular problems arise from the volunteers' reliance on tools they neither control nor have the expertise to adapt in any significant way to better enable temporal sensemaking. First, the lack of extensibility in representing a wider range of temporal metadata limits the usefulness of the collected information. Second, the inability of the tools to accommodate volunteers' distributed information crowdwork practices undermines the real benefits of collective temporal sensemaking—a task that automated tools are not yet able to (and may never) reliably perform. Both factors are a huge source of frustration for the team.

To further probe these issues, we concluded each of our interview sessions with a "magic wand" question as a cool-down exercise for the volunteers. During this part of the interview, participants were asked to creatively speculate about improving SBTF work practices and/or the technologies

they appropriate in their work. In this section, we present a small sample of our participants' informal design ideas indexed to the temporal sensemaking practices—*triage, evaluation, negotiation,* and *synchronization*—that SBTF employs as a way to illustrate how these practices might be more effectively instantiated in both the volunteers' work activities and the technologies that support their work.

6.1 Imagining Different Roles of Scale as a Response to the Demands of *Triage*

The relatively manual nature of information triage is both a source of frustration and a point of pride for the volunteers. Every volunteer stated a clear preference to stay closely connected to the flow of information to help them stay on top of current conditions, anticipate trends, and spot meaningful outliers. As overwhelming as it may be at times, collectively navigating the rhythms and patterns of the social media data stream is an essential part of constructing a shared sociotemporal order across the team while everyone is in the thick of the data deluge during the triage process [37].

It was particularly interesting during this portion of the interview to hear volunteers wonder about how to *scale* their work, a term typically used to describe process improvements through automation. Here, one volunteer muses about the desire to scale as a way to encourage *more* human ingenuity and creativity in information seeking. This stands in contrast to the significant body of prior research that looks to computational approaches to extend capacity, such as dynamic filtering [29], functional information management [52], and other systems-based interventions that further regulate crisis informatics work.

> ***P5:*** *I can't predict how easy it is to implement because it depends on volunteer interest and availability. It is what we were talking about with educating people about the kinds of resources to look for. Any kinds of analysis to do. They're already kind of getting it but a little bit more, I don't want to say standardized, because that's not exactly what I mean. 'Cause, you know, sometimes the standard becomes a pair of blinders.*

Scale also comes into focus as another volunteer, independently, imagines ways to multiply the network effects of digital humanitarian work by rethinking its structure:

> ***P8:*** *I get the feeling that the way to scale is to make an organization that could be more distributed... being able to scale up somehow making semi-autonomous cells that amplify our work. In order to do that, each volunteer becomes a little coordinator within a network. What kind of organization do we need if we really like to scale this up: 10X? 100X? How can we tap all this good will, time, abilities, and availability of devices and connections? What kind of tools do we need to make this incredibly distributed powerful thing work?*

This speculation also considers creative ways to deploy the team to improve sensemaking during the crucial information triage phase. But it goes further by confronting a pragmatic reality: the intertwined frictions of this unique form of people-powered distributed work with the real limits of appropriated, off-the-shelf cloud collaboration tools. Throughout its history, SBTF has operated with a relatively flat organizational structure. Activations involve experienced subteams of "super volunteers" called *Core Team* members who lead the project alongside *Coordinators* who provide tactical support. Both subteams engage directly with the *Volunteers*, who are the heart of the information-gathering work. The idea offered by P8 introduces a radical restructuring of SBTF: essentially, atomizing distributed sensemaking across the larger organizational network. With the possibility of re-configuring the distributed labor comes new opportunities to reconsider the current make-shift set of tools that are ill-suited to hundreds of people collaborating simultaneously but may more effectively serve smaller teams working in parallel.

6.2 Imagining How Custom Metadata Might Streamline the *Evaluation* of Temporal Representations

Assessing the recency or "freshness" of crisis data is a crucial component of distributed digital humanitarian work. Even richly detailed, comprehensive information from a reliable source may be less valuable to responders if it is not timely, particularly in the early moments of a crisis when SBTF is called in to curate situational awareness. Several volunteers suggested that new ways of engaging with metadata could help to improve collective understanding at the evaluative phase of temporal sensemaking. A generative but fairly low-fidelity idea is to direct volunteers to append categorical assessments to their data entries on the Google Sheet:

> ***P6:*** *Maybe adding a field that is you know, where you score the post for relevance or something so then you could sort on those.*

> ***P5:*** *We could verify [by] classing info by our confidence level.*

While not explicitly temporal, these speculations could easily be adapted to incorporate evaluations that flag key temporal data, such as inconsistencies between timestamps and social media content. Additional evaluative layers also lend themselves well to the volunteers' preference to triangulate temporal and non-temporal information as a way to help bolster the trustworthiness of the collected data.

The fast pace of temporal sensemaking in this context, compounded by a fairly unrelenting "fire hose" of social media posts, invites opportunities for especially clever ideas. One volunteer, fully embracing their magic wand power, described how to reduce temporal sensemaking burdens through the use of dynamic heat mapping that makes visible the status of temporal narratives constructed by one's volunteer colleagues and helps to identify opportunities for additional triangulation and assessment:

> ***P9:*** *So you use a filter to filter out everything ... and then you use the time slider to see how dots on the map become strong or weak. They fade out when it's over, they fade in when your slider is approaching a high activity.*

The idea of using temporal metadata as an interactive visual element in an imagined information system points to the innovative HCI work embraced by temporal design [49], foregrounding and drawing attention to multiple, co-existing temporalities. Likewise, the slow technology agenda [40], which posits the need for interfaces that support moments of reflection in the midst of high-pressure, productivity-focused activity, is another potential mechanism for radically rethinking tool support for sociotemporal coordination.

6.3 Imagining Tools that Cluster Data to *Negotiate* Temporal Relationships

Some of the thornier information breakdowns faced by the SBTF volunteers are exacerbated by the limited metadata available on the consumer-facing social media platforms and the flat data structures used by Google Sheets. Lacking the ability to efficiently relate data and reassemble it inspired the volunteers to think about how to more effectively organize and cluster data for their purposes.

One volunteer reflected on how Google Sheets could be transformed into a relational database as a more sophisticated way to query disparate data on-the-fly while the team continues to triage, evaluate, and enter information sources about the crisis:

> ***P9:*** *As a volunteer, you could work very fast without bothering too much about the structure. You should relate to only your data to stitch them together. And then behind the work you are making it [a] relational database.*

The spatio-temporal relationship between time and place is especially important for constructing situational awareness during a crisis. Negotiating *where* and *when* an event has occurred within acceptable bounds of confidence, accuracy, and speed is quite challenging within the constraints of the appropriated tools used by the team. Speculating about this use case, another volunteer describes how the data can serve two purposes to advance the negotiation process: pattern-matching through visual map representations that trigger relational clusters of spatial information over time:

> ***P6:*** *... if you have multiple reports coming in at different times, showing spatio-temporal data on a map is hard. But it might be interesting to use clustering or something like that where you, when you click on the cluster, it opens up all the different reports and it could highlight all of the records that are associated with that point. So for a single point at that hospital, it may have been entered five different times because you found five different reports for that hospital. So if you clicked on the point, it would then promote to the top of the table the five records that pertained to it.*

In other words, the ability to generate an overview of the curated data as a connected and dynamic knowledge base could help uncover the temporal breakdowns between the current data and predictive signals in order to draw attention to information that requires further investigation from a volunteer and identify complete, actionable information that is suitable for sharing with emergency responders.

6.4 Imagining How to Better *Synchronize* the Team Through Feedback

A desire for more feedback was mentioned during all of the interviews. In particular, respondents were curious about the ways in which the sum of each volunteer's distributed contributions connect to a broader network of knowledge that drives SBTF's work practices, mission, and culture. In other words, volunteers were interested in knowing how their individual work adds to the *collective mind* [11, 72] of the organization.

One low-fidelity suggestion related to this synchronization practice looks to tweak how the Core Team and Coordinators use Slack—the primary chat application that the group appropriates to communicate in real-time during an activation and which serves as a documentary archive to reference for future crises, as needed:

> ***P6:*** *Often, volunteers come on for an hour or something, and they're not going to read through the last 23 hours of Slack posts to get up to speed. So just kind of putting out little public service announcements on Slack every hour or something so that everybody's seeing that information, you know, kind of a little digest of all the important things that we learned over the last hour.*

Posting a periodic summary of curated data, information, and insights gleaned over time provides in-the-moment support to the volunteers as they stitch together the collective temporal narrative while also advancing a broader sense of unity, productivity, and teamwork in the act of sensemaking. This kind of solution also shifts the burden of constructing and sharing the emergent temporal narratives from the individual volunteers to the collaboration platform, itself, enabling volunteers to get "up to speed" and engage in their individual sensemaking tasks more quickly and easily when logging on.

More elaborate ideas to foster *collective mind* coalesced around the notion of a feedback interface that displays group progress and shared awareness with a sense of fun. Such an interface aims to motivate deeper engagement and playful competition in the often-frustrating task at hand of aligning disordered timestamps and other temporal cues in emotionally charged social media data. In this case, a "gamified" dashboard interface is envisioned to more light-heartedly synchronize the team's activity:

> ***P6:*** *... dashboards that are kind of tracking everybody's statistics, kind of gamifying it a little bit and showing a leaderboard of contributions. People seem to really like that and respond to it. And not just the, like, who's ahead, who's posting the most, 'cause we don't want people just going crazy just to get their numbers up and they're not being very careful. But also just the overall group accomplishment. Like, how many we've collected, you know, the numbers of posts and … show the progress getting toward that goal. So sometimes those kind of graphic things are just motivating 'cause you can see that you're making progress and that you all collectively making a dent in this thing. But, also, there was some healthy competition.*

It is worth noting that even given permission to invoke fanciful future technology developments and wide-ranging organizational changes to SBTF, the volunteers that we interviewed largely focused their attention on changes that augmented the existing work practice of volunteers, expanded the capability of existing coordination tools, and leveraged the established competency of the SBTF organization. There is strong validation in these responses about SBTF's organizational and sociotechnical effectiveness in making sense of chaotic, incomplete, and mis-aligned social media data during the aftermath of Hurricane Maria.

The imagined future capabilities shared here generally layered in additional scale, structure, filtering, and coordination capabilities on top of existing tools and practices. They also largely complemented and aligned with the distinct phases of temporal sensemaking discussed earlier in the interviews (but without our drawing attention to these activities in the framing of the "magic wand" question), providing additional evidence for the importance of these activities as constituting the key information crowdwork practices of the organization.

7 REFLECTIONS ON TEMPORAL SENSEMAKING

Sociotemporal order [74] is a complex social process for constructing a shared agreement about "what time it is" and then ascribing collective meaning to the time so that we can put it into practice as calendars, work shifts, train schedules, and the like. Developing this shared narrative about time involves sensemaking. Drawing from Weick and others, Ancona describes sensemaking as a way to tell a story by developing plausible understandings and meanings about unknowns, testing against others' understandings, and then refining a collective understanding as new information becomes available [4].

Temporal sensemaking, embodied in telling the story of sociotemporal order, also requires untangling pluritemporality, the multiple and simultaneous ways that SBTF volunteers encounter time in their work [37]. Here, temporal sensemaking contends with understanding mechanized forms of time, e.g., clock time, timestamps, algorithmically structured social media timelines, etc., alongside qualitative forms of time, e.g., information life cycles, temporal references in social media posts, etc. The interplay between talking in mechanized crisis data and talking in qualitative human experiences highlights a crucial temporal sensemaking tension—one that is further amplified by the distributed nature of the global team which exists in its own temporality of multiple time zones and diurnal cycles.

Exploring how SBTF volunteers approach sensemaking to construct collective understandings of high-tempo crisis information reveals interesting synergies between Weick and Roberts' [72] formative work on retrospective sensemaking and the present-oriented narrative framework espoused by Cunliffe and Coupland [12]. In this context, the past-versus-present sensemaking perspectives become less a matter of competing descriptions and more of an opportunity to view temporal sensemaking as a dynamic continuum of volunteers' responses to crisis information rapidly unfolding over time. This is exemplified (and lamented) by one volunteer as:

P9: *The value of that information we collected had a very short life.*

The pace by which sensemaking must take place for SBTF volunteers blurs the demarcations between retrospective sensemaking and a narrative constructed in the flow of the moment, as Cunliffe and Coupland suggest, when the retrospective lookback may be measured in mere hours.

Temporal sensemaking in the globally distributed digital humanitarian work conducted by SBTF is nuanced and subtle. Temporal understandings are interleaved with the collective wisdom of *prior* activations, the *immediate* facts presented inside the crisis zone, and the capacity to *anticipate* the availability of future data about the crisis.

Several of the interview excerpts in our findings illustrate how sensemaking is also influenced by rapid cycling of the past, present, and future of the crisis, itself. Natural hazards, epidemics, and other crises have their own temporal trajectories [35], as do the humanitarian data generated by them. Thus, understanding how temporal sensemaking takes place and the opportunities to intervene to improve timely and trustworthy digital humanitarian work matters a great deal for data-informed crisis response.

In our analysis, we identified four approaches to temporal sensemaking—***triage, negotiation, evaluation,*** and ***synchronization***—that SBTF volunteers used to collectively construct a temporal narrative to organize time- and safety-critical information during the Hurricane Maria humanitarian crisis in Puerto Rico.

In practice for SBTF volunteers, ***triage*** is a rapid, time-constrained process of manually sorting online information about the crisis, largely from social media streams. The "fish or cut bait" nature of triaging high-tempo information encapsulates an obvious tension between Weick and Robert's conceptualization of retrospective sensemaking [73] and the present-minded narrative perspective of Cunliffe and Coupland [12]. As one volunteer lamented, using standards discerned from sensemaking of prior activations to guide information triage can be helpful. But those same standards can become blinders that run the risk of placing arbitrary limits on the temporal sensemaking process for unique aspects of the current crisis. Speculations by the volunteers about scaling their work offers a way to potentially bridge this past–present sensemaking tension. In particular, the moderately radical idea of restructuring the distributed team into semi-autonomous networks has the potential to increase the agility of the organization, enabling smaller, more dynamic teams of volunteers to engage with the data streams at different socio-cultural and spatio-temporal timescapes [2]. These imagined practice-based approaches also address a common refrain among the volunteers that "technology is not the solution for everything."

Whereas *triage* brought past–present sensemaking frictions to the foreground, the ***evaluation*** process engages with both chronological viewpoints by relying on triangulation to assess the timeliness of the data under scrutiny. Rapidly comparing multiple data points, e.g., temporal metadata, temporal references in the online content, and non-temporal content, demands both retrospective *and* in-the-moment sensemaking approaches in order to gauge the reliability of the information since timestamps alone are notoriously poor indicators of "freshness," according to the volunteers. Each of the suggested evaluation work practice improvements incorporate classifying or filtering data as a way to seamlessly glide between past and present sensemaking as the team works to construct a temporal narrative about conditions on the ground. This evaluative approach also lends a reflexive touch to sensemaking as a dynamic, interactive process, suggesting that it is not necessarily as predictable or unidirectional as the theories might imply.

Sensemaking about events happening across time and space presents particular cognitive challenges for the volunteers when they are engaged in the ***negotiation*** process. As Weick writes about the response to the deadly Mann Gulch wildfire [72], "People, including those who are

smokejumpers, act as if events cohere in time and space and that change unfolds in an orderly manner." The resulting disorder that occurs in catastrophic events, like humanitarian crises, demands negotiation between the order people *want* versus the disorder they *encounter* [37]. Cunliffe and Coupland concur here as well, suggesting "that in the moment, legitimacy, coherence and closure can be elusive and contested because different meanings are multiply-constructed across different moments of time and space" [12]. We found it especially interesting that the SBTF volunteers' speculations to improve the data negotiation aspect of their temporal sensemaking suggested ways to more clearly draw attention to relationships in the data—here, as an *ad hoc* relational database to surface patterns, clusters, and/or spatial information—to facilitate both retrospective and prospective information seeking as a way to help resolve breakdowns in the sociotemporal order.

Finally, team ***synchronization*** was the last step used in constructing temporal narratives that cohere across the distributed SBTF teams who are engaged in collective sensemaking about the crisis. While the previous sensemaking approaches, ***triage, evaluation*** and ***negotiation*** can incorporate individual or group information work, *synchronization* requires shared agreement across a number of factors. The volunteers' speculations for how to better facilitate synchronization focused primarily on expanding the capabilities of the communicative tools used within the organization; this resonates strongly with Weick and Roberts' definition of the *collective mind* as taking place through conversation and telling of organizational stories [73]. Likewise, the strong "narrative" component of Cunliffe and Coupland's present-oriented formulation—collectively negotiated interpretations of an event [12]—rely heavily on a medium in which fluid discourse and storytelling among the narrative's interpreters is possible, allowing them to continuously articulate their own narratives, reinterpret others', and "riff" off of one anothers' accounts. Both sensemaking, broadly, and synchronization, more specifically, have interesting improvisational attributes which we plan to explore in future work.

8 LIMITATIONS

Although we took care to invite a wide variety of SBTF volunteers to share their stories about the Hurricane Maria activation and the challenges of conducting their work and utilized best practices for conducting and analyzing qualitative interview data in this research (e.g., reflexive bracketing, interviewing until theoretical saturation was achieved), the research presented here is still only the story on a single organization at a single point in time. Although the rich descriptions presented here provide a valuable perspective on SBTF's response to a particular crisis situation that is clearly representative of other kinds of globally distributed digital humanitarian crowdwork, there is a limit to the generalizability of these stories to other crisis response organizations and/or distributed sensemaking teams. Additional empirical research will be needed with members of these other organizations to triangulate findings and determine which aspects of the temporal sensemaking practices might be truly unique to the experiences of these volunteers.

The other primary limitation of our study is the retrospective nature of our inquiry. Because we wanted to gather multiple perspectives on a single event in which SBTF activated at a significant scale, we chose to ground our empirical study in the Hurricane Maria response as one of the largest-scale activations that SBTF volunteers experienced during the broader arc of the first author's participant–research with the organization. This was also the *last* large-scale activation that SBTF was asked to undertake. However, these events took place approximately 22 months prior to our conducting the interviews reported here. Although we scaffolded our conversations with our participants by sharing organizational documents and chat transcripts that were captured at the time of the crisis response, it is possible that the passage of time might have blurred recollection of some aspects of the volunteers' work.

Finally, in the year following the data collection undertaken for this study, the SBTF Board of Directors dissolved the organization after determining that its 10-year mission had been met and that new technology-centric products/services were either duplicative or exceeded the technical capacity of the organization to adopt and maintain (internally). However, the work practice, ICT, and temporal challenges illustrated in this study remain salient to other digital humanitarian groups, as well as hyper-local crisis response initiatives, such as grassroots mutual aid self-help networks [60].

9 CONCLUSION AND FUTURE WORK

In this study, we explore how a globally distributed digital humanitarian team constructs a collective temporal narrative in order to make sense of dynamic, high-tempo information in time- and safety critical information work. We make two main contributions to the CSCW and social computing community to better understand the impact of sociotemporality on distributed collaboration—a rising form of remote labor and important topic in the future of work. Bridging between the empirical and theoretical, we present a temporal sensemaking framework describing how the team uses a process of *triage, evaluation, negotiation* and *synchronization* to approximate a "data story" from temporally-fluid information shared by people on social media in the midst of crisis that, once assembled, is actionable by emergency responders. Further, we contribute design speculations, prompted by the study participants themselves and indexed to each of the temporal sensemaking approaches. In future work, we plan to use this scaffolding to design and prototype tools for globally distributed humanitarian teams that incorporate improvements to overcome the sociotemporal disorder that is ever-present in this class of crowdwork. Our data suggest that actionable solutions in this space will need to contend with the lack of flexibility in the appropriated assemblages of existing, cloud-based collaborative sociotechnical tools that these kind of remote teams use to conduct their work.

10 ACKNOWLEDGMENTS

This research was supported by US NSF grant IIS-1564275. Thank you to the anonymous reviewers for their thoughtful and constructive feedback that immeasurably helped to improve this work. We are also deeply grateful to The Standby Task Force (SBTF), the study participants, and our colleagues with Project EPIC, the Philanthropic Informatics Research Lab (PIRL), and the Too Much Information (TMI) Lab for their support.

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Received January 2021; revised July 2021; accepted November 2021