Towards an Understanding of Digital Disaster Response Workflow in Humanitarian Emergencies

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Abstract. This paper examines the workflow of digital volunteers during disaster response operations. It reveals how digital volunteers engage in sense-making activities to filter crowdsourced information to warrant confidence that the data satisfies standards of engagement, production and analysis. We do so by studying a digital disaster response organisation - Humanity Road - through seventeen response operations across thirteen countries using digital ethnography over a period of sixteen months. Data collection incorporates a diverse range of sources including Skype chat logs, field notes, social media postings, and official documents. The findings are used to develop a framework that provides an analytical lens for understanding information workflow on the use of crowdsourcing in the humanitarian response operations. Our findings suggest practical implications for both the digital humanitarian organisations and governments of the disaster-prone countries.

Introduction

We are living in a world of emergencies and disasters in which even countries favoured by geography or advanced technologies are not entirely insulated. Historically, disasters are characterised with the episodic mass influx of goods, services and volunteers that converge to provide relief using collective behaviour and role enactment [4,34]. With the advent of mobile technologies along with the development, adoption and increasing accessibility of web 2.0 technologies, the convergence phenomenon that was hitherto observed on-site are now found online by remote digital volunteers [21]. Likewise, past studies revealed that disaster affected communities relied on official and unofficial information sourced from social media [43,44]. The news sourced from social media often act as a source for supporting community resilience when the disaster strikes to enable them to sustain, survive and reunite [50]. Using this information, volunteers can harness collective intelligence using crowdsourcing to provide situational awareness information for decision making as a form of aid [11,26]. However, their emergence has disrupted the old response playbook of standard operating procedures of emergency response organisations [48].

The focus of this paper is on the established volunteers, unlike most of the existing literature which addresses the activity of spontaneous and unaffiliated volunteers. Specifically, our paper examines the disaster response workflow and crowdsourcing activities of volunteers working under a US-based digital disaster response organisation called Humanity Road (HR). HR is chosen as a case study organisation based on the following reasons. First, its potentials in adding to our knowledge a peculiar case of how groups are organised, socialised and work together in a virtual space. Second, its work practice also has the potential to highlight how people, organisational culture, and process, as well as technological tools and platforms, are entangled with one another. This paper therefore seeks to answer the following research question: *What are the activities involved in processing crisis information among established digital volunteer communities?*

Thus far, the existing literature concerning the internet-enabled volunteer groups have tended to address the socio-technical challenges associated with Humanitarian emergencies on three broad themes. First, the studies that explore the verification and information processing activities of unaffiliated and spontaneous groups [9,30,46]. Second, works that approach this phenomenon from a more technical perspective related to the development of platforms/tools, and models and framework for extracting disaster information [18,22]. Finally, studies that seek to understand the work practice of the established groups [47]. The latter studies focusing on social media and data aggregation communities as an established group have delimited their scope to concentrate mostly on one case study or investigating one disaster type or articulate the usage of a tool/application over a short period. While insightful,

these studies have not comprehensively touched on the activities involved in processing crisis information. This was the motivation behind this study to take a step further and investigate this vital yet underscored aspect of information processing within the social media and data aggregation communities.

As a result, this paper contributes to the existing research by introducing a new framework derived from empirical data developed explicitly for the social media and data aggregation communities. This framework emerged from the analysis of data gathered from eight types of disaster covering 13 countries within 16 months. The proposed framework provides a structured, scalable and coherent information workflow on the use of crowdsourcing in humanitarian response operation which forms the theoretical contribution of our paper. By taking a holistic approach to studying different disaster types of various scales, across continents over a more extended period, we differentiate ourselves from prior studies regarding methodology by analysing different data sources. These data sources included field notes from participant observation, digital records of the case study organisation, Skype chat logs and interviews. Employing different data sources allowed us to offer a thick description of how volunteers acquire, process, vet and share actionable information [15]. Consequently, this approach provides a unique contribution to the methodological advancement of disaster research within the Computer Supported Cooperative Work (CSCW) and crisis informatics fields.

The remainder of the paper is organised as follows: Section 2 provides a review of the related studies. Section 3 discusses background and case study context. Section 4 presents the data gathering approach, and in section 5 and 6 we present and discuss our findings and its implications. In section 7, we conclude our work.

Related Studies

The Literature on digital disaster response is broad-ranging and cuts across disciplines and fields. Our review suggests a lack of consensus in naming these Internet-enabled communities from practitioners and academics. For example, terms such as digital volunteer [communities] [32] digital humanitarians [actor networks] [38], volunteer and technical [technological] communities [17,52] have all been used in various studies and across disciplines. This lack of consensus became visible following the publication of Disaster Relief 2.0 where members of digital humanitarian organisations openly disagreed with the authors of the report for giving

their various communities a catch-all label as 'volunteer and technical communities' [45]. For clarity, we refer to these communities as Digital Volunteer Communities (DVCs).

As mentioned in the introduction, our focus is on the established digital volunteer communities. Gorp [17], delineates established digital volunteer communities into software platform development communities, mapping communities, expert network communities and social media and data aggregation communities. We situated our work within the social media and data aggregation communities by studying the collaborative and social computing aspect of HR volunteers and their crowdsourcing activities.

The initial phase of crisis informatics literature on internet-enabled volunteers revolves around understanding self-organisation of emergent groups on the one hand and that of organised response by the established groups. Emergent groups are informal digital volunteers that spontaneously converge as bystanders during a disaster and disappear shortly because their advent and actions are extempore and therefore exclusive to the catastrophe [24]. On the other hand, established digital volunteer communities are further divided into two groups. The first group called Virtual Operations Support Team (VOST) derived its membership mostly from retired and serving professional emergency management staff [7]. The second groups include "…[N]etworks of technical professionals with deep expertise in social media, geographic information systems (GIS), database management, [and] online campaigns [who apply] their skills to some of the hardest elements of the disaster risk management process" [1:2].

Disaster sociologist described collective behaviour of emergent group as unaffiliated, convergent and spontaneous [24]. Interestingly, crisis informatics researchers have observed that the difference between offline and online convergence behaviour is in the immediacy in which information and people converge as well as the distance from which people can contribute to the relief effort [20]. Conversely, established volunteer communities are organised and non-ephemeral. Unlike emergent groups that exhibit collective behaviour, Kreps and Bosworth [24] argue that established groups' exhibits formal organising behaviour. The authors further argued that "formal organising starts with a clear understanding about domain [D] and tasks [T] (i.e. what is being done, by whom, and how) before resources [R] are mobilised, and activities [A] takes places (ibid, pg. 300). Contrary to formal organising, with collective behaviour,

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activities [A] take place and resources [R] are mobilised before such understanding exist. The sequencing of the organisational element is A – R- T- D" (ibid, pg. 300).

A review of past studies of the established digital volunteer communities tended to focus on three distinct categories of responders. The first category explores the coordination between digital volunteers and formal/traditional humanitarian relief organisations [37]. The second segment examines their relationship with emergency management agencies [9]. The third category deals with the virtual operation support team (VOST) on the one hand, and digital volunteers on the other [30,46]. Although VOST offers support remotely like any other digital volunteer communities, it is regarded as a distinct entity from the spectrum of the digital volunteers because unlike digital volunteers; its membership came from retired professional emergency management staff who have an internal connection to different emergency management organisations (EMOs) and aids agencies [6].

As digital volunteer communities began to mature, scholars have also examined their trajectories and offer insight on how they are changing the landscape of disaster response. For example, Palen et al. [30] explore the path of Humanitarian OpenStreetMap through the lens of two major disasters and provide a glimpse of how it organises its activities. Similarly, Starbird [45] has explored the information processing activities of HR volunteers by examining the management of information using a specific case study of Sacré Coeur hospital following Haiti 2010 earthquake. On the other hand, Starbird & Palen [46] provide an insight into the organisational development and work practice of HR where they traced its origin, identity negotiation, membership and the nature of its work. Nonetheless, these studies have limited scope with regards to the contexts, the use of tools and the duration upon which the response lasted. For instance, in the case of the Peru Earthquake, the entire response operation lasted for 3 hours and involved eight volunteers (ibid). As such, our paper, builds on such contributions by observing 17 response operations across 13 countries over a period of 16 months, to provide a holistic understanding of how volunteers acquire, assess, process and scrutinise crowdsourced information. The exploration of such activities will, therefore, contribute to the better understanding of the behind-the-scenes information processing activities of DVCs. Such findings will thus serve as a benchmark for evaluating whether the kind of information services these communities are providing satisfied standards of engagement, production and analysis.

Methodology

Regarding the case study context, HR uses Skype as its core platform for coordinating its activities. These activities are mainly organised in 4 different Skype 'windows' named as HR Café, HR Urgent Events, HR Useful Links, and HR Work Diary. 'HR Café' is a window in which volunteers are using as a resort for socialising and exchange pleasantries. 'HR Urgent Events' window is the central hub where volunteers coordinate and monitor the ongoing event around the world. The 'HR Useful Links' window is another resort where volunteers post new life hacks, tips, notes, and links while HR Work Diary is serving as a platform for volunteers to stop in and drop a note on what they have been working on so that other team members can stay informed. In addition to these 4 main windows, HR has separate Skype windows for committee meetings, special projects, internal drills and training. HR creates an event-specific window whenever it is responding to a significant catastrophe.

Our methodological approach to understanding this collaborative and social computing phenomenon is through virtual ethnography which allows researchers to better understand online activities and the impact of the relationships between people and technology [2,19]. Recent studies in CSCW and Crisis informatics have promoted the use of such methods [10,47].

We used field notes from participant observation, digital records of the case study organisation, Skype chat logs and interviews as our primary source of data. The first author participated in thirty meetings in which twelve related to strategic and operational aspects of the organisation, while the remaining eighteen were associated with volunteer training. Drawing from the theory of role and self [16], the first author took the role of participant-as-observer where he spent the time to take part in the real disaster response activities. Our first author signed up as a volunteer four months before he approached HR leadership for wanting to study their response work as part of the strategy to gaining access. During the induction, the first author introduced himself as a research student whose interest revolves around crisis informatics with a concern on digital disaster response and crowdsourcing. By the time our first author obtained ethical approval to carry out the research and approached

HR, the request was granted and he was asked to insert the word "Researcher" in front of his Skype name so that other volunteers will be aware of his presence in all the Skype chat rooms Later, a formal announcement was made about his intention to study the activities of the HR volunteers.

The Skype chat logs involved only the response operations that our first author participated or observed from 15th February 2016 to 22nd May 2017. We interviewed 7 volunteers through Skype to find out comprehensive information about the work practice of HR volunteers which lasted between 60 to 120 minutes.

This paper uses 17 selected digital disaster response operations undertaken by HR as its primary unit of analysis. To choose those responses, we consider Fritz's [14] core properties of disasters – events, social units, response – as our basis for case identification and selection. Accordingly, we attempted to cover a broad range of disasters such as dam spillage, earthquakes, explosions, flooding/landslide, hospital project, severe weather, tornado, wildfires. This is to enable us understand volunteers' activities from different emergency response operations. Also, our case selection covers 13 countries (social units) drawn across 6 continents (Africa, Asia, Europe, North America, South America, Oceania) with a different type of activation (response) as shown in Appendix 1. Our basis for selecting these events is to have insight into whether there are differences in approach or procedures across different disaster types or countries in volunteers' response work.

Our approach to data analysis is qualitative. As such, we draw from Corbin and Strauss' [8] procedures, and previous examples in CSCW papers [12,33]. Following that, we review and analyse field notes, chats log, interview transcripts, and digital records iteratively and inductively to find recurrent themes. At the first instance, we began our analysis by making sense of the entire Skype chatter covering the 17 major response operations, thereby extracting themes and subthemes based on our research objectives. Later, we used Activity Theory Oriented Design Method (AODM) and Martins & Daltrini Framework as an interpretive frame for analysing the composition of activities and understanding the social organisation of digital volunteers' work using collaborative computing applications. AODM and Martins & Daltrini Framework are methods for operationalising Activity Theory (AT) framework in some specific context [36]. Kaptelinin, Nardi, and Macaulay [23] argue that the high-level nature of AT framework does not provide prescriptive solutions that can be applied to specific contexts

for certain activities. AODM [29] offers a unique simplification of activity system components and practical questions for capturing each component in a template. The method allows for analysing individual and collaborative practice. On the other hand, Martins & Daltrini [25] framework provides the lens for the identification of a component of the activity system for each activity as well as the decomposition of each sub-activity into actions and operations. The integration of these methods helps in making the analysis more focused. To illustrate how each activity is distinct from one another, we highlighted both the primary constructs of the activity theory (subject, object, tools, communities, the division of labour, and rules) alongside actions, operations and activities using bold italic in the finding sections.

Findings

The purpose of this study was to find out the type of activities involved in processing crowdsourced information. We begin by discussing the process workflow that emerged based on the repeated occurrence across a range of disasters during our sixteen months' observation.

Our observations, along with a careful review of Skype chatter across a range of disasters, revealed an implicitly structured workflow. This workflow starts with the Monitoring and Activation in the first phase and continues with Listing, Listening & Verification, Amplification and ends with Reporting. The categorisation of each phase evolved based on the type of actions, operations as well as the outcome of each distinct activity. Besides, the classification was also made with the full realisation of the means, through which activity is carried out, as well as rules and regulations governing the conduct of such activity.

In what follows is the explanation of our findings on the nature of the cooperative work of the HR digital response. The portion of the Skype chatter we illustrate here usually starts with a date and time stamp ([12/03/2016, 20:17:29]) followed by the name of the volunteer that mostly begins with a prefix HR. The Skype chatter portion also includes emoticons that volunteers usually insert in between the message they want to pass across.

Monitoring & Activation

In the context of the HR response work, monitoring is defined as an activity that relates to tracking the sudden onset or the arrival of a slow-moving disaster. The activity serves as the first phase of its response workflow. Monitoring is

usually undertaken by active volunteers (subject) who make use of a different range of applications *and platforms* (tools) for receiving an instant push notification on their mobile's phones, PCs and tablets among others. HR's volunteers make use of websites like the Global Disaster Alert and Coordination System (GDAC), U.S. Geological Survey (USGS), the National Hurricane Centre (NHC) and Pacific Disaster Centre (PDC) as their most preferred sources of news. However, HR volunteers are *encouraged to avoid* (rules and regulations) breaking news websites and traditional media outlets for reporting the sudden onset or arrival of slow-moving disaster. This is because volunteers have learned over the years that '*some of these media sources have the history of publishing information very fast, but often get their facts wrong*' (Skype Chat, Chris Thompson - HR President). Against this, HR volunteers were *encouraged* (rules and regulations) during orientation to subscribe to electronic notification systems (ENS) provided by PDC, GDAC, USGS, and NHC. The rationale is HR regards PDC, GDAC, USGS, and NHC as the widely acknowledged official source for disaster information and in which most of the news outlets are getting their news from such centres

By subscribing to the ENS, HR volunteers receive an *SMS or email* (tools) whenever a disaster happens or is about to happen. Notification received via these websites sometimes offers a snippet of the disaster impact that helps volunteers to start preparing for a response. The following snippet from the Skype chat logs illustrates how a volunteer received an instant alert and announced to the Urgent Event window about the sudden onset of Earthquake in Alaska:

[12/03/2016, 20:17:29] HR Nicholas Lawson: I just got a phone notification of a magnitude 6.4 EQ near Atka, Alaska – alert doesn't give depths – will look for that – EQ occurred at *18:06 UTC 👻 👻

Fig. 1. Snapshot of Skype logs extracts 1. - Illustration of notification alert.

As soon as such type of information is posted into the Urgent Event window, available volunteers that are hanging around in the Café will start reporting to the Urgent Event window. Following such *announcement* (action), *Disaster Desk Working Group* (community) – a subcommittee among active volunteers – will quickly discuss whether to keep monitoring the situation or activate the Disaster Desk depending on the impact of the event.

In disaster parlance, activating the Disaster Desk is guided by the likely impact of the disaster, and this impact is categorised in stages.

For example, local events that are smaller in proportion is classified as Stage 1 (Green) activation. In this instance, volunteers that are available at that time can be organised under the guidance of Social Media Incident Commander (SMIC) to undertake the response operation. During stage 1 (Green), volunteers will be asked *to datamine social media for urgent needs* (action) and route it to those offering help and vice versa.

Stage 2 (Yellow) activation is declared when the event is severe and humanitarian emergency organisations are or are likely to be overwhelmed and could not be able to respond to urgent needs promptly. In this instance, Disaster Desk Working Group (DDWG) will advise SMIC to invite both *active and inactive volunteers* (subject). In the HR parlance, active volunteers are those volunteers that are socially active at 'Cafe' and shares useful information from time to time at the 'Useful Links' window. On the other hand, inactive volunteers are those volunteers that have access to HR windows and resurface only when they receive invitation requesting their participation in a major catastrophe. Available volunteers will then be asked to undertake '*general monitoring*' (action) and **collaborative authoring** (action) of a 'situation report' (SitRep). During stage 2 (Yellow) activation, all regularly scheduled meetings and training sessions of HR may be temporarily disrupted.

Stage 3 (Code Red) is named for massive catastrophe with mass fatalities usually needing international aid. Code Red activation requires a collective effort of both active and inactive volunteers. SMIC usually sends *activation invitations* (outcome) through text messages and email to both active and inactive volunteers requesting for their help. Moreover, the Incident Commander will also post the same announcement in the Urgent Event window and will create a new Skype window for managing the response. The following excerpt is a sample of activation information posted to the Urgent Event window by the event SMIC:

[03/10/2016, 17:50:01] HR Javon Malone: ✪ Attention team, we anticipate activation this afternoon for Hurricane Matthew. This is a very large storm that will likely impact multiple countries. The DDWG is preparing for our response now. This will likely be a Yellow and quite possibly Red event. We ask that if you are able to sta rt clearing some time in your schedule the next 3-4 days to support our activation. We have a window set up and gave designated this event as Operation Atlantis. Thank you. 🌷🌷🌷

Figure 2. Snapshot of Skype logs extracts 2: Activation announcement.

In the above extract, the SMIC began the message with the star ✪ emoticon and ends the activation announcement with three emoticons of

flower 🌷🌷🌷 (rules and regulations). The message also shows that HR volunteers have previously been monitoring the slow movement of the disaster.

In summary, *monitoring and activation* is an activity that starts with the *tracking of news* (action) using smartphones, *PC and tablets* (tools) through an ENS. The activity is carried out by *active volunteers* (subject) whom upon receiving credible information will send it to the urgent event window. On receiving the news, a *DDWG* (community) among the active volunteers will discuss the matter based on the available data and decide the type of response HR volunteers will provide. As soon as the *decision* (outcome) has been reached, the SMIC will be asked to send invitation depending on the activation level. Following that, volunteers will begin to announce their readiness to support the response operation. The arrival of the volunteers to the urgent event window signifies the end of the monitoring and activation phase and the beginning of the Listing phase in the HR response workflow.

Listing

The second phase of the HR response workflow begins as soon as volunteers announced their readiness to support the response operation. If it is a stage one (Green) response, all the activities will be carried out within the *Urgent Event window* (tool). However, Stage two (Yellow) sometimes begins in the Urgent Event window. Nonetheless, as soon as it escalates to a full-scale disaster, then a new event-specific window will be created, and available *volunteers* (subject) will be added to it.

The Listing phase (activity) in this context involves a series of actions which begins with the *identification of keywords and event hashtags* (actions). Later, volunteers will work concurrently (depending on their capabilities) to *produce* (outcome) a list of websites, social media handles, locations, phone numbers, and email addresses of organisations involved in the administration of relief. Some of these institutions include emergency management organisations and agencies at federal, regional and local levels. Additionally, the activity in this phase involves finding information about traditional aid agencies (Save the Children, Doctors without Borders (MSF), critical infrastructure companies, airports, roads, hospitals, telecommunications, and special interest groups such as DAFN (Disaster, Accessibility and Functional Needs) and animals in disasters. The SMIC handles the coordination of *task distribution* (division of labour) to volunteers depending on their area of competence. As soon as the SMIC allocates tasks to the available volunteers based on their expertise or preference, volunteers will then work in a self-directed mode to produce the required information. They do so by searching the internet, and social media platforms. Later, the SMIC will or ask a volunteer to add the Twitter accounts into the HR's Twitter list.

Unlike the 'Monitoring & Activation' phase in which the activities are in sequence, the Listing phase often connects to the next phase (Listening & Verification) in a back and forth manner depending on the nature of the catastrophe. If the situation is not complex and does not need major response effort, the workflow is a straightforward activity. As such, the sequence will be from 'Listing' to 'Listening & Verification' phase. However, if the response initially pertains to only one area, but later the situation keeps escalating, and various regions are added to the emergency declaration list, then the activity will continuously be in a cyclical iteration between the two phases as illustrated in Appendix 2, Figure 3. Moreover, our observation reveals another phase called 'Reporting' also connects directly to 'Listing' phase during major events. The two dotted arrows in Appendix 2, Figure 3 becomes active whenever the event is declared to be a major one, and as such, there is a need for updating the 'Listing' resources whenever the emergency declaration covers new areas as the event keeps unfolding. With the maturity of the stage, volunteers' attention will now be directed to *monitoring Scanigo, data mining urgent needs* and *listening to the social media feeds* of emergency management organisations, relief agencies and special interest groups (actions). The commencement of such activities signals the transition to the next phase even though the listing phase activity may not necessarily come to an end.

Listening and Verification

'Listening & Verification' are separate activities that occur concurrently but leading to one outcome – production of actionable information. In the context of HR, the Listening phase involves the use of automated tools, such as Scanigo, and manual approaches to crowdsourcing actionable information that is relevant to the response operations. Such actionable information includes finding damage reports, request for help, evacuation, medical supplies, missing person or information about reunification centres. It also involves searching for isolated and disadvantaged communities, tracking the activities of other digital volunteers and aid agencies as well as listening to online Emergency Telecommunications groups such as

Ham Radio and First Response Radio Team (FRRT). On the other hand, Verification involves fact-checking using tools, platforms and search engines to determine the integrity of data sourced by volunteers at the listening stage.

In undertaking the listing activity, volunteers make use of a different range of *technological tools and platforms* (tools). For instance, volunteers who attended training on how to monitor social media using Scanigo and are confident in using it will be added to the Scanigo platform. Other volunteers utilise a range of search engines (Google, Bing, and Yahoo), social media platforms (Facebook, Twitter, Instagram), social media aggregation dashboards (HootSuite, Social Mention, TweetDeck, TweetReach), official websites and reverse image searching tools such as Tin Eye among others.

As soon as volunteers tracked actionable information such as the urgent need, they will then share it to the Urgent Event window or Event specific window (depending on the type of response HR is providing) for validation. In short, Finding and tracking information is an activity on the one hand and verifying such information is another activity on the other hand. HR have procedures for verifying sources, links, photos, and locations among others. If the information is found to be good enough, the next stage is for social media listeners/messengers among the volunteers to start amplifying the information while other volunteers will start transferring the verified information to the SitRep (reporting). Listening and verification will continue in a back-and-forth manner until HR stands down. The reason is, throughout the disaster life circle, volunteers will keep tracking actionable information, and verifying its authenticity.

Previously, we have shown 'Listing' and 'Listening & verification' workflow move either in sequence or in back and forth manner; however, in this phase, the workflow sequence moves in the forward direction to the next phase called 'Amplification'. In addition to that, during major events, our observation reveals a linkage between the 'Reporting' phases and 'Listening & Verification' phase. This activity evolves when the situation warrants writing a series of SitReps. As such, volunteers' co-authoring reports will be transferring vetted information from the Skype response window and keep adding them to the Google Docs for authoring the SitRep. An illustration of the workflow is in Appendix 2 – Figure 4.

The figure shows the process workflow at 'Listening & Verification phase' with the 'Listing' as a preceding activity and 'Amplification' as the next stage in the process. The figure also shows a dotted arrow from 'Reporting' phase linking to the 'Listening & Verification' phase. Listening & Verification are ongoing activities until when the disaster desk Incident Commander announce volunteers to stand down.

Amplification

Amplification (activity) comes into effect as soon as volunteers tracked and verified critical information which needs to be routed to emergency management organisations or disaster-affected communities. The act of sharing such information is what is called amplification. More precisely, amplification involves carrying out four distinct activities. These activities include *sharing verified official information* (action), *routing urgent needs* (action), *distributing survival tips* (action) and *encouraging ethical sharing* (action) of disaster messages.

While the responsibility for tracking and verifying urgent needs could involve any volunteer, amplifying urgent needs through HR social media platforms is only administered by designated HR *social media listeners/messengers* (division of labour). This is because social media listeners/messengers are added as administrators for HR's social media platforms and undergo specialised training. They, therefore, have the administrative privilege to post information on behalf of the HR. However, any volunteer can post verified information through own social media account. Volunteers usually make use of *GroupTweet* (tool) to amplify information. GroupTweet is a third-party application where multiple contributors can tweet from their personal Twitter account, and the tweet will appear in the official HR Twitter account. Others make use of Twitter, Facebook, Instagram and other social media dashboard and aggregation tools like Buffer and Hootsuite (tools).

From the context of response workflow, the sequence that leads to 'Amplification' phase starts from 'Listening & Verification', and the iteration will continue in back and forth manner between listening and verification phase to the amplification until the disaster desk stands down from the response activity. The rate at which HR volunteers amplify information depends on nature, impact, and the affected area(s). It is worthy to note that HR amplifies such information across its social media platforms and also encourage volunteers to also amplify the same information through their social media handles.

Reporting

'***Reporting***' (activity) refers to the act of producing written accounts of verified actionable information that will offer situational awareness to the emergency managers, relief organisations and disaster-affected communities to sustain, survive and reunite. Reporting also involves producing a summary account of response activities undertaken by volunteers as a mechanism for shared awareness among volunteers. The essence is to enable volunteers joining response operation half way to quickly read through and understand what is going on and what needs to be done. It comes into effect depending on the nature of the disaster. If the catastrophe needs long hours of response, then HR volunteers will start co-authoring SitRep at the same time amplifying and this will be going on until the response is over.

As previously mentioned at the listing stage, sometimes listing activity feeds directly into the reporting stage in which volunteers ***add*** (action) accounts of interest into the ***SitRep*** (tool) when the event escalates from Yellow to Red. In addition, listening and verification phase connects to both amplification and reporting phases once volunteers have verified information. However, when the situation is in Green, the process workflow is straightforward in which only listening & verification phase connects to the reporting phase. Figure 5 (see appendix 2) illustrates the process workflow connecting to reporting phase in a back and forth manner.

The response workflow as illustrated in Figure 5 shows three phases – listing, listening and verification and reporting. In the first phase (listing), whenever the response is in either Yellow or Red, volunteers will start ***adding*** (action) the account of interest to the SitRep (Google Docs). As such, the flow will be in the continuous back and forth manner until HR stands down. Also, at the second phase (listening and verification), the process workflow connects to the reporting phase by ***adding*** (action) verified actionable information to that phase. The process is also continuous unless the response operation is called off. The figure (5) depicts the workflow where volunteers working on the Reporting phase can go back either to the Listing or Listening & Verification Phase. For example, the situation might warrant the need for the original lists to be updated when the disaster covers more regions.

Monitoring the activities of HR have revealed that, in mediating the cooperative work of authoring the SitRep, volunteers make use of four primary tools/platforms (tools). First, volunteers make use of Skype as a central platform where all the chatter for mediation, verification, and sense-making takes place. Second, the use of 'Event Status Google Sheet' as a reference point where all the instructions, guides and tip sheets, are carefully assembled. Third, the use of Google Docs in which volunteers collaborate to co-author the SitRep. Fourth, the use of Scanigo for filtering, categorising and ranking torrents of tweets to reduce the time taken for data mining crisis information manually. Additionally, volunteers using the Firefox browser can appropriate HR's plugin while responding to the catastrophe. The custom-made plugin provides a handy dashboard where volunteers could easily find pre-written searches, guides, tips, a list of embassies, twitter lists, emergency numbers and loads of useful information.

Therefore, it is through the integration of the tools mentioned above and platforms and series of discussions volunteers produce such type of reports. The tools and platforms mentioned above are central to the work of HR while coordinating the collaborative authoring of SitRep. However, at the individual level, volunteers utilise a range of tools while crowdsourcing information. Such tools include social media platforms and aggregation dashboards, translations tools, reverse image processing tools and platforms, mapping tools and customised HR's Firefox add-on among others.

From our findings, partners such as the United Nation Office for the Coordination of Humanitarian Affairs (UNOCHA), FEMA, Americares, and Cisco TacOps uses HR SitRep for situational awareness and decision making associated with communication, funding and cooperation. SitRep also guides partners to know who is doing what and where among other aid workers and relief agencies.

In brief, HR's digital disaster response workflow starts with a set of activities evolving into five distinct phases. The categorisation of these activities into stages grew out of the textual analysis of the data based on activity theory methods. The response workflow starts with monitoring and activation and connects to the listing activity in a constant iteration when the activation level is in yellow or red. Following that the workflow will continue from listing to listening and verification phase in a back and forth manner. At the listening and verification phase, the workflow connects to both amplification phase as well as reporting phase. The iteration will continue until when the Disaster Desk calls for volunteers to stand down.

Discussion and Implications

Throughout this paper we tried to provide insights into how Digital volunteers go through a

set of distinct yet closely inter-linked activities during disaster response operations. In what follows, is the discussion arising from such findings.

Regarding our research question that sought to answer the type of the activities involved in processing crowdsourced information, our findings uncover five (5) distinct activities involved in processing crisis information. These activities are: 1) Monitoring & Activation, 2) Listing, 3) Listening & Verification, 4) Amplification, and 5) Reporting. Interestingly, such list of activities appeared in every disaster response studied in this research. The distinctiveness of each activity is identified and defined through an interpretive frame of activity theory methods. The approach allows for the classification of each phase through the number of actions, operations and outcomes involved in each activity. In the light of these findings; this section will discuss some critical insights derived from our research question.

Accordingly, based on the results of the study in the investigated contexts, this paper proposes an analytical framework that offers a fresh perspective and deeper insight into the activities of the digital humanitarian response process workflow as shown below in Figure 6.
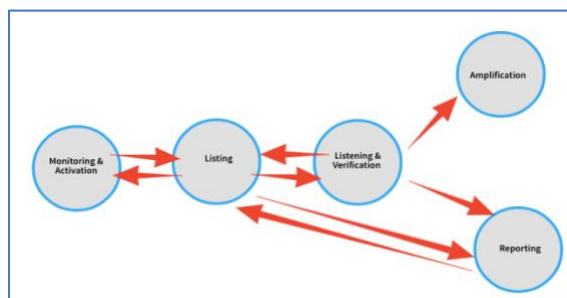

Figure 6. Response workflow model

The proposed workflow holds the essential steps to understanding digital disaster response activities. These steps were carefully analysed and cross-checked across eight (8) disaster types in thirteen (13) countries during seventeen (17) response operations as explained in the finding section. The conceptualisation of these phases gives an exciting insight into the activities of HR. This model is high-level enough to allow academics, practitioners and system designers make sense of HR's response workflow. At the same time, it provides detailed interpretations of each step in the process and how they are dynamically and reciprocally related to one another. The proposed model is both flexible and scalable in such a way that it can be followed as a roadmap and applied in different contexts across diverse disaster types with different impacts and scales. This scalability covers the

disaster type, impact, affected region and the country. The disaster impact refers to the number of casualties, property and infrastructural damages. The affected region could be isolated communities or urban areas. Countries could take the form of developed or developing nations since the HR response lies entirely on the information available online and the emergency response system of the country in question.

The proposed model provides a broader view of the activity phases involved in processing crisis information across disaster types by HR volunteers. Regardless of the type of response HR is providing – Green, Yellow, Red - the initiation phase begins with Monitoring & Activation and connects directly to the Listing phase. If the activation is declared to be Green, the response workflow will be in sequence. For example, the process will entail listening and verification of crisis information. Once volunteers discovered and verified urgent needs or official information, it will be amplified and later reported. However, if the activation is Yellow, Listing activity will connect to Listening & Verification phase in a back and forth manner. If the event is Red or was in Yellow and later escalates to Red, the listing will connect to both the Listening & Verification phase as well as Reporting Phase. At that stage, the activity will involve adding the resource list to the Sitrep (Google Docs). At the Listening and Verification phase, the response workflow connects simultaneously to both amplification and reporting phases until the disaster desk asks the volunteers to stand down.

Consistent with Kreps and Bosworth [24] thesis on the borderline between formal organising and collective behaviour in disaster as discussed in the literature review section, this study corroborates the sequencing of activities as exhibited by the HR volunteers. From our findings, the workflow shows that there was an element of understanding about the domain [D] and task [T] among the volunteers before resources [R] are mobilised and activities [A] takes place. This aspect could be seen right from the monitoring stage, where there is a marked understanding of how to monitor disasters using the appropriate technological tools and platforms. This awareness is also noticeable in all the subsequent stages. For instance, the ability of the disaster desk working group (DDWG) to decide on whether to keep monitoring or activate the desk, as well as the type of activation, is another pointer to understanding the domain [D] and tasks [T]. Others are the distribution of tasks on who is doing what and where. For example, as soon as disaster desk is activated, activities such as identification of keywords and hashtags, producing a list of websites and social media

handles, data mining urgent needs and amplification of verified information are sub-activities that are allocated at the appropriate stage to available volunteers. With this, it can be argued that our workflow has insightful similarities to the workflow of established traditional emergency management organisations in which there was an element of understanding about domain and task among the volunteers before resources are mobilised and activities take place.

In retrospect, past studies that examined workflow on the use of ICTs in humanitarian emergencies tended to cluster around Volunteered Geographic Information (VGI) and management information systems [5,6,31,40–42]. Unlike in this study, some of these studies are technical and deal mostly with studying decision support systems alongside their development and deployment. However, this workflow model shares some commonalities and differences about task initiation and completion with most of these earlier studies. By juxtaposing this workflow with that of Ostermann and Spinsanti [31] in which the authors evaluated the credibility of Volunteered Geographic Information (VGI), one can observe some similarities and differences. For example, Ostermann and Spinsanti's conceptual workflow includes four steps that begin with 'retrieval' and move through 'processing', 'integration' and ended at the 'dissemination' phase.

At the retrieval phase, the system retrieves relevant social media and other disaster information using keywords. Next, when the data is retrieved, the workflow will continue with the processing phase where the location and source profile data will be picked and later use to determine relevance, credibility and analysis of the information. The workflow will then continue to the next phase (integration) in which the output generated from the processing phase will be combined with the information from official and authoritative spatial data infrastructures.

Lastly, the result of the integration will then be shared (disseminated) across the stakeholders. In other words, both workflows have initiation and completion phases. The phases also share some commonalities. For example, the listening & verification phase in this workflow can be likened to their second and third phases, and their final phase also can be likened to the reporting phase in this current study. Both studies also aspire to evaluate the credibility of the information produced using crowdsourcing. However, the parting point is that the central concern of this study is offering insight into the activities involved in processing crowdsourced information from digital volunteers related to social media and data aggregation communities

while their studies focus was on the Volunteered Geographic Information (VGI).

Following on from this, we now turn to examine the collaborative and social computing activities performed by volunteers during each response operation. These areas include: tools manipulation, task organisation, communication style, and the group shared awareness:

Tool manipulation: The response workflow mentioned earlier also reveals how HR volunteers are manipulating tools to produce contents. While the use of such devices is common knowledge, but how HR team is shaping the tools in the context of disaster response is what makes this interesting. For example, during a typical response, the HR team uses Skype for coordination, Google Docs for collaborative authoring, Google Sheets as information and project management/reference manual, and Scanigo for listening to social media postings. In other instances where the response dictates the need for more training to volunteers or briefing (like the Burundi Hospital response), HR will use a Google slide deck to visually present ideas to its volunteers. As such, the ability to combine automation alongside manual work such as the use of Scanigo or switching from one platform as well as searching or posting information using a mobile phone or desktop computer to another platform suggests a combination of creativity, experience and skills.

Task Organisation: Observing HR workflow also enabled us to understand how they organise activities by dividing the task among themselves. For example, in the Listing phase, the work involves finding health facilities, embassies, telecommunication companies, emergency management organisations and relief agencies among others. At Listening & Verification, some volunteers' role will be listening to isolated communities, others on reunification information and another team will be charged with data mining urgent needs. When it comes to Amplification, some volunteers will take the role of posting information to HR tweeter account, while others will work on Facebook or Instagram. But how they work out what to do and who to do what while responding depends on the available volunteers, their skills, knowledge of contexts, and the nature of the response – slow moving or sudden.

Communication Approach: Another insight associated with our findings involves the nature of information exchange where the communication is characterised using abbreviations, emoticons, typing errors, hedging, emphasis and terminologies. Use of acronyms such as BRB for 'be right back', EQ for an earthquake, SitRep for situation reports and TC for tropical cyclone among others is replete in all

their communication. Likewise, HR standardises the use of some selected emoticons for shared awareness among volunteers. Our observation also reveals the manifestation of caution such as 'heads off' or 'unverified' while posting information to prepare the mind of fellow volunteers.

Group Shared Awareness: The concept of shared awareness within a group is well established in the CSCW literature [3]. Our observation notes how 'Reporting' in the form of 'morning summary', 'evening summary' and 'end of the day summary', among others, plays a significant role in a response operation. During response operations, the HR team will assign a member to take the role of giving a summary and posting it to the Urgent Event window. The reason for this is to make everyone involved aware of the ongoing response, since volunteers' work based on their availability.

Professionalisation and Awareness of Humanitarian Principles

A closer and thoughtful look at the findings of this study could potentially reveal some elements of professionalisation and knowledge of awareness of humanitarian principles with regards to the activities involved in processing crisis information. This outcome is contrary to some earlier studies findings positing a 'marked lack of understanding of operational aspect of emergency response' [28:25] and being less equipped in respect of understanding their boundary of operations [13,39]. Others argued about a lack of professional training and an inability to maintain a professional standard [37]. In the finding sections, this study demonstrated that:

a) By training and in practice volunteers prefer to get notifications from 'authoritative official sources' just like the way traditional media sources tended to receive their alerts in the event of sudden onset of disasters such as earthquakes.

b) The culture of allowing people to have access to their operation rooms only after attending HR internal training and understanding its operational rules as well as signing its code of conducts. This code of conduct demands a volunteer to abide by its principles of safety, lawfulness, responsibility, good fellowship, loyalty, and integrity. Also, the code requires the volunteer to pledge and agree with UN humanitarian principles of neutrality, impartiality and humanity.

c) The culture of sharing survival tips, reassurance messages, and cautionary messages that encourages the global online public to share only verified facts from official sources as well as discourages sharing photos and locations of emergency workers.

As such, the above attributes imply some levels of the awareness of humanitarian values, knowledge areas and level of skills proficiency. These attributes are what past studies have described as a core set of competencies required by humanitarian actors [51]. A possible explanation for the misalignment of these findings may be due to the lack of broader understanding of the different roles community of volunteers play. For instance, some of these studies criticising lack of professionalisation and standards focus mostly on exploring the crisis mappers activities [28,37]. This lack of a broader understanding of the work of different digital volunteer communities could also offer a clue to the possibility that digital humanitarian literature is yet to recognise the existence of emergency telecommunications communities (ETC). This community provides a different type of service to other digital communities. However, their activities have not been captured in Milner and Verity [27] as well as Gorp's [17] classification of Digital Volunteer Communities. A possible explanation could be either the group's impact has not been noticed at the beginning, or such communities have not aligned themselves with the Digital Humanitarian Network as at the time of publishing their studies

Practical Implications

The main contribution of this paper is that it has generated essential and valuable insights into the activities involved in processing crisis information. As a result, its findings suggest implications for practice for digital humanitarian organisations, emergency management agencies, governments of disaster-prone countries as well as directions for future research. This paper has sketched out how the crisis information data is monitored, processed, managed, verified and reported. The understanding of this process was made possible as a result of the methodological consideration of studying different types of disasters across nations of varying infrastructural densities, resilience, socio-historical, and cultural differences. This choice as argued in our methodology section was to uncover whether the type of response operations provided by HR differs from one country to another. As explained in the finding section, our analysis revealed a consistent process workflow across all disaster types in which the study covers.

However, the findings also revealed a stark difference in digital disaster response readiness

across developed and developing nations. The discovery of such differences in digital disaster readiness presents an exciting implication for researchers, developing countries and disaster practitioners. For example, researchers can begin to think of how to establish a benchmark for digital disaster readiness by studying digital disaster ready nations and comparing them with the available online information on the developing nations. It is also possible for practitioners to learn how to improve their response workflow by developing information resources list of disaster-prone countries before the sudden onset of disasters. The resource lists shall contain information such as emergency numbers, websites, locations, maps, social media handles of fire, ambulance, police, airports, transportations and emergency response organisations. By populating the list on a country by country basis, organisations such as HR could reduce the time taken at the listing phase while responding to disasters. Thus, the HR process workflow could be reduced to monitoring & activation, listening & verification, amplification as well as reporting. By doing that, the response process efficiency will improve, and HR will be more responsive in providing information as a form of aid.

Equally important, by bringing to light the work of HR, there is a potential for governments in developing nations to partner with such organisations on areas related to preparedness, response operations, resilience, process improvement and digital disaster readiness. This is because past studies have shown that 80 to 90 per cent of disasters that frequently occur at the global level take place in developing countries that lag in essential but efficient infrastructure such as uninterrupted power supply, heating, and telecommunication services among others [35]. Against this background, the findings of this study along with others can serve as a basis for preparing on how to seriously synergise the activities of digital disaster organisations within the realm of the international humanitarian system.

Conclusion

This study contributes to the Computer Supported Cooperative Work (CSCW), Crisis Informatics, Information Systems for Crisis Response and Management (ISCRAM), and Disaster field in two ways: theoretically and methodologically.

As to the theoretical contribution, this study proposes a new analytical framework outlining the various stages/activities involved in the digital disaster response related to social media and data aggregation communities. Comprehensively derived from the empirical data, this framework contains the critical components that could potentially signal the emergence of new models for DVCs with regards to the social media and data aggregation Community. Our model evolved from diverse types of disasters with different scales and is flexible enough to support multiple scenarios of similar kinds and to be adapted to various disaster types and used by Social Media and Data Aggregation Communities with comparable characteristics in different countries and settings.

Regarding the methodological contribution, this study is among the few that attempts to empirically and comprehensively understand and shed light on the information processing activities of the established digital volunteers. As mentioned previously, this study employed various data collection methods from 8 disaster types in 13 countries, across 6 continents, covering both developing and developed nations using virtual ethnography over the period of 16 months. To the best of our knowledge, this methodological approach is the first of its kind in this area with regards to the DVCs focusing on social media and data aggregation communities. Additionally, this study is among the few that provides prescriptive operationalisation of AT by combining AODM and Martins-Daltrini framework. This approach provides a unique interpretive frame for analysing the composition of activities involved in processing crowdsourced information. As a result, this work offers a distinctive contribution to the methodological advancement of disaster research within the CSCW, ISCRAM and crisis informatics fields. Taking this approach has provided a holistic understanding of the behind the scene processes and measures in digital disaster response.

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Appendices

Appendix 1

Table1. Summary of the disasters used in the study

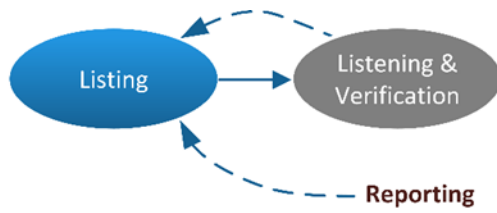| EVENTS (TYPE)	ANALYSIS PHASE	SOCIAL UNITS		RESPONSE
		COUNTRY	CONTINENT	
Dam Spillage	Phase 1	USA (Oroville)	North America	Red
Earthquake	Phase 1	Japan (Kumamoto)	Asia	Red
	Phase 1	Ecuador	South America	Red
	Phase 1	Italy	Europe	Yellow
Explosion	Phase 1	Belgium (Brussel)	Europe	Green
	Phase 1	Turkey (Istanbul)	Asia	Green
	Phase 1	Manchester (UK)	Europe	Green
	Phase 2	Westminster (UK)	Europe	Green
Flood/Landslide	Phase 1	Sri Lanka	Asia	Green
	Phase 1	Peru	South America	Yellow
	Phase 1	USA (Louisiana)	North America	Red
Special project	Phase 1	Burundi	Africa	Purple
Severe weather	Phase 1	Fiji Tropical Cyclone	Oceania	Green
	Phase 1	USA (Oklahoma)	North America	Green
	Phase 2	Hurricane Irma (USA)	North America	Red
Wild fire	Phase 1	Canada	North America	Yellow
	Phase 1	Chile	South America	Green
Legend		Combined participation with the observation		Observation only

Appendix 2

Fig. 3. Illustration of the 'Listing' phase.
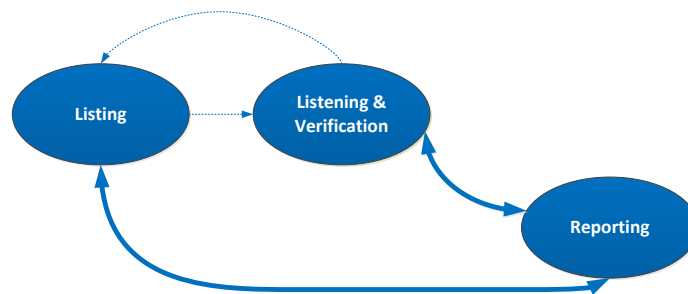

Fig. 4. Illustration of the 'Listening & Verification' phase.

Fig. 5. Illustration of the 'Reporting' phase.