Social Media in Command & Control: A proof-of-principle experiment

T.J. Grant
Retired But Active Researchers (R-BAR)
tim.grant.iscram@gmail.com

F.L.E. Geugies
Ministry of Defence (NL)
fle.geugies@mindef.nl

P.A. Jongejan
Netherlands Defence Academy
pa.jongejan@nlda.nl

ABSTRACT

The literature on the organizational use of social media in crisis response and management is largely concerned with communication between organizations and the general public ("citizens"). By contrast, there are few papers on the use of social media within organizations for operational purposes. One essential operational capability in such organizations is Command & Control (C2) or its equivalent. Our research focuses on the use of social media in C2 for crisis management at the operational and tactical levels. To enable the use of social media in C2, Jongejan and Grant (2012) extended Reuter, Marx and Pipek's (2011) theoretical framework. In the research reported in this paper, the extended framework was tested by performing a proof-of-principle experiment for a famine relief scenario with human subjects in the laboratory. The results show that more extensive concept demonstrations and field experimentation are justified.

Keywords

Laboratory experiment; crisis management; coalition; self-synchronization; network-enabled capabilities.

INTRODUCTION

The literature on the organizational use of social media in crisis response and management is largely concerned with communication between organizations and the general public ("citizens") (Jongejan & Grant, 2011). By contrast, there are few papers on the use of social media for operational decision-making purposes within an organization (Yates & Paquette, 2011). One essential operational capability in crisis management organizations and coalitions is Command & Control (C2) or its equivalent. Our research focuses on the use of social media in C2 for crisis management at the operational and tactical levels.

Reuter, Marx, and Pipek (2011) proposed a two-by-two matrix framework of social software infrastructure for communications between organizations and citizens. Jongejan and Grant (2012) extended this framework to C2 in crisis management organizations, in which the control loop must be closed between operational units that handle the crisis on-site and a centre that monitors and controls those operations. In the research reported here, we conducted a proof-of-principle experiment to test whether or not the extended framework could be implemented using social media. The laboratory experiment was performed using e-mail, Twitter and CrowdMap and a simulated famine relief scenario, with human subjects modelling the operational units and the control centre. E-mail and Twitter[1] were used for inter-subject communication, and CrowdMap[2] – a derivative of Ushahidi – was used for shared situation awareness.

The purpose of this paper is to describe the design and performance of a proof-of-principle experiment to test Jongejan and Grant's (2012) extended framework for C2 communications using social media. A proof of principle (a.k.a. proof of concept) is the realization of an idea, concept or theory to demonstrate its feasibility or potential for use (Wikipedia, 2013). Such an experiment is usually small, and typically employed to raise the Technology Readiness Level (Mankins, 1995) from TRL 2 ("Technology concept and/or application formulated") to TRL 3 ("Analytical or experimental critical function and/or characteristic proof of concept").

[1] See https://twitter.com/.

[2] See http://ushahidi.com/products/crowdmap.

In our research, Jongejan and Grant (2012) is at TRL 2, because it formulated a concept or theory for using social media in C2. Given that the experiment was conducted within the context of a bachelor student's capstone project[3], time and resources (finance, computing hardware and software, laboratory space and facilities, and human subjects) were strictly limited. Nevertheless, we regard this as a completed piece of research that achieved its research goal. The results indicate that it would be worthwhile to initiate Concept Development & Experimentation (CD&E), leading to wider application in the crisis response and management community.

This paper consists of four sections. Following this introductory section, Section 2 summarizes the underlying theory and literature on social media, and describes Jongejan and Grant's (2012) extension of Reuter et al's (2011) framework. Section 3 describes the design, performance, and analysis of the proof-of-principle experiment. Finally, Section 4 draws conclusions and makes recommendations for further research.

RELEVANT THEORY

Social Media

Kaplan and Haenlein (2010, p.61) define social media as "a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of user-generated content". They regard Web 2.0 "as the platform for the evolution of Social Media" while user generated content (UGC) "can be seen as the sum of all ways in which people make use of Social Media".

On the basis of media richness and the extent of self-disclosure, Kaplan and Haenlein (2010) classify social media into the categories of collaborative projects (e.g. Wikipedia), blogs (e.g. Twitter), content communities (e.g. YouTube, Flickr), social networking sites (e.g. Facebook, LinkedIn), virtual game worlds (e.g. World of Warcraft), and virtual social worlds (e.g. Second Life). Under this scheme, CrowdMap, Ushahidi, and the like can be regarded as collaborative projects.

Kietzmann, Hermkens, McCarthy, and Silvestre (2011) identify seven functional building blocks (identity, conversations, sharing, presence, relationships, reputation, and groups) of social media. Different social media activities are defined by the extent to which they focus on subsets of these building blocks. They illustrate these differences for LinkedIn, Foursquare, YouTube, and Facebook. In functional terms, Twitter focuses primarily on conversations, and CrowdMap on sharing and presence within a geographical context (i.e. a shared map).

Social Media in Crisis Response Literature

There is an extensive literature on the use of social media in crises. In Jongejan and Grant (2011) we surveyed ISCRAM proceedings from 2004 to 2011. Papers on the use of social media in crisis response started appearing in the literature from 2008 onwards. Initially, these were case studies of the spontaneous use by citizens for self-help purposes, e.g. Vieweg, Palen, Liu, Hughes, and Sutton (2008). The first papers on organizational use of citizen-generated content appeared in 2010, e.g. Starbird & Stamberger (2010). The key issue that has emerged was validating and integrating the information so gained. C2-related applications first appeared in 2012. Denis, Hughes and Palin (2012) described the use of a volunteer team to filter social media content for organizational decision making during the 2011 Shadow Lake forest fire. The authors are also aware of a Royal Netherlands Army unit that used Facebook via smartphones to monitor and control vehicle maintenance activities for a week, instead of their normal C2 system (Boekhout, 2012). Manso and Manso (2012) proposed a holistic approach to using social media in crisis response that, like Jongejan and Grant (2012), distinguished Public Protection and Disaster Relief (PPDR) organizations from First Responders. Nevertheless, the emphasis is still on citizen-generated content. By contrast, our research focuses on communications between PPDRs and First Responders.

Reuter et al (2011) framework

Reuter et al (2011) discuss how the professional actors involved in crisis management and the affected citizens can communicate and collaborate using social media. Their research goal is to recommend the creation of an infrastructure that integrates information from the different online communities and helps the official crisis management by providing and receiving information. They propose the two-by-two matrix shown in Figure 1 as the basis for the social software infrastructure for communication between organizations and citizens. The matrix is agnostic with respect to the communication's form (e.g. voice, text, visual) and medium (e.g. carried

[3] The second author was the student, and the other two authors were his supervisors.

by sound, light, or radio waves.

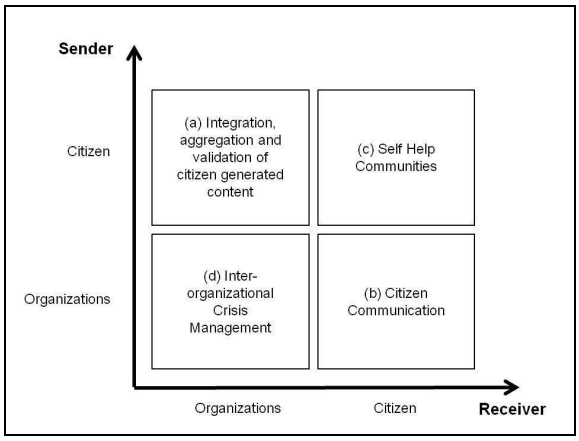

Figure 1. Communication matrix for a social software infrastructure (Reuter et al, 2011, Figure 5).

In quadrant (a), citizen-generated content is integrated with and validated against the recipient organization's own information, assisted where possible by the use of crisis tags previously provided to citizens by the organization. In quadrant (b), organizations broadcast information to inform, warn, and communicate with citizens, either as individuals or as groups. This could include the provision of crisis tags. Quadrant (c) represents peer-to-peer communication between citizens, as employed in a crisis to provide self-help within (emergent) communities of interest. Communication in quadrant (d) supports information sharing between organizations for crisis management purposes.

C2 and Network-Enabled Capabilities

The C2 process is defined as "*the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission*" (US DoD, 2011). The C2 process is supported by a C2 system, defined as *"an arrangement of personnel, equipment, communications, facilities, and procedures"* (ibid). The functions of the C2 system include *"planning, directing, coordinating, and controlling forces and operations*" (ibid). A key enabler for effective C2 decision making is situation awareness, defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1988). In a coalition, situation awareness must be shared across the partner organizations.

Traditionally, military C2 is directive, with decision-making authority situated at the top of an organizational hierarchy. However, within the past 15 years, this business model has changed under the increasing influence of telecommunications networking technologies (and the Internet in particular). Under the "Network Enabled Capabilities" (NEC) model, robust networking and collaboration leads to shared situation awareness, better decision making, and ultimately better mission effectiveness (Alberts & Hayes, 2003). While the hierarchical structure of superior-subordinate relationships may be retained, superiors define the mission in terms of goals ("mission command" in NEC terminology) and the subordinates are empowered to determine the means by which these goals will be achieved. A key consequence is that units may coordinate their actions with their peers without first obtaining authorization from their CPs; this is known as *self-synchronization*. When two or more subordinates resolve a resource or timing conflict by peer-to-peer negotiation, without referring to their superior(s), then self-synchronization has occurred. Self-synchronization speeds up decision-making and action. Many civilian crisis response organizations already operate according to the NEC model.

Extending Framework to Incorporate C2

Taking cybernetic control theory (Ashby, 1956) as a starting point, Jongejan and Grant (2012) extended Reuter et al's (2011) framework by dividing each organization into a Control Process (CP) and a Process Under Control (PUC). Reuter et al's citizens represent the organization's Environment. The resulting three-by-three matrix is shown in Figure 2. Citizen to citizen communication (Reuter et al's quadrant (c), Self-help) is unchanged from Reuter et al's original framework. Content generated by citizens (quadrant (a), Citizen-generated content) is received on behalf of the organization by the PUC. Likewise, the PUC sends information to citizens on the organization's behalf (quadrant (b), Citizen communications). Inside the organization, two new categories of

communication are added: Observations are sent by the PUC to the CP, and Instructions are sent by the CP to the PUC. In military terminology, observations are known as situation reports (SITREPs), and instructions take the form of plans or operation orders (OPORDERs). Additionally, Reuter et al's quadrant (d), Inter-organizational coordination could be divided into two parts. Tactical-level coordination between organizations takes place between the organizations' CPs. Operational coordination between organizations occurs between their PUCs on-site, i.e. they self-synchronize.

			Receiver		
			Organizations		Citizens
			CP	PUC	
Sender	Citizens		(N/A)	(a) Citizen-generated content	(c) Self-help
	Organizations	PUC	Observations ITREPs)	Self-synchronization (intra-organizational)	(b) Citizen Communications
		CP	(d) Inter-organizational coordination	Instructions (OPORDERs)	(N/A)

Figure 2. Extending Reuter et al's (2011) framework to incorporate C2 theory.

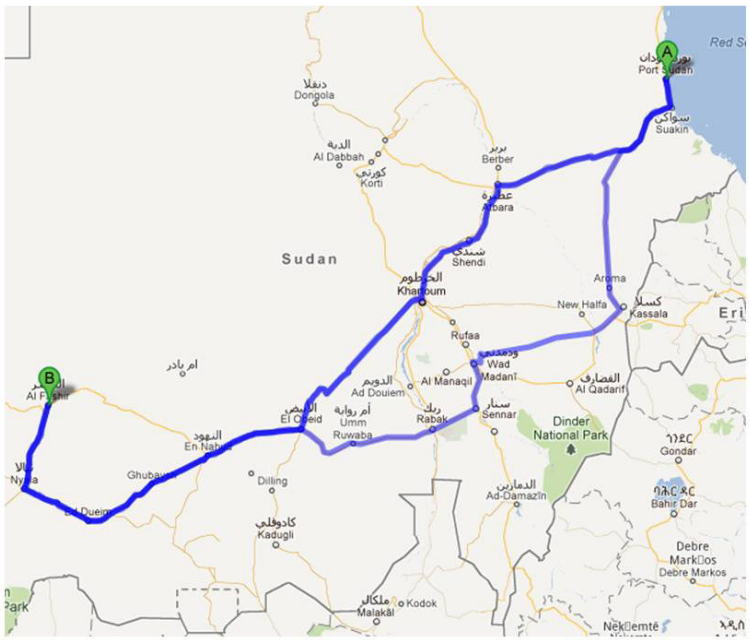

Figure 3. Map of Sudan with two routes.

PROOF OF PRINCIPLE EXPERIMENT

Experiment Design

The aim of the experiment was to test whether or not Jongejan and Grant's (2012) extended framework could be implemented using social media. A positive outcome would be indicated if implementation by social media led to a faster, better, and/or cheaper response. This implied that there must be two primary experimental conditions: C2 without and with social media. For the purpose of the experiment, we chose to define a simulated scenario based on famine relief operations in Darfur, Sudan. We assumed that food would be supplied from outside the Sudan, arriving by ship at Port Sudan. From there, the food would be transported overland to Darfur by truck convoy. Inspection of a large-scale map of Sudan (Figure 3) shows that there are two major routes: a northerly route via Khartoum (the capital) and a southerly route via Kassala, Wad Madani, Sennar, and Rabak.

The scenario concentrates on the overland part of the operation.

For the manner in which the operation is controlled and managed, we took our inspiration from how the UN Office for the Coordination of Humanitarian Affairs (OCHA) operated after the January 2010 Haiti earthquake. OCHA makes extensive use of volunteers. In Haiti, OCHA sought volunteers by broadcasting tasks via a web-based platform called ReliefWeb. Prospective volunteers responded by telephone or e-mail. This gave us the baseline for our experiment, Condition A, in which e-mail is used. In Condition B we replaced e-mail by Twitter, together with CrowdMap for sharing situation awareness. Condition B was originally divided into two sub-conditions: with Twitter but not CrowdMap, and with both social media. However, this would have required more experimentation time than we had available within the context of a bachelor project. In consequence, we cannot split out the contribution of Twitter from that of CrowdMap. However, both Twitter and CrowdMap meet the definition for being social media, allowing us to satisfy our research goal without distinguishing their respective contributions.

The simulated relief organization was assumed to have a headquarters distant from Darfur (e.g. in Europe). In control theory terms, this headquarters was the CP. The PUC consisted of multiple units in Sudan: the truck convoy, a supplier of diesel fuel, and the relief organization's local representative in Khartoum. The Game Manager (GM) simulated other actors external to the scenario, such as the harbour authorities in Port Sudan and a truck repair company. The actors and their respective roles in the scenario are shown in Table 1. For details of the task briefing for each actor, see Geugies (2012), Annexes E to I.

Table 1. Roles in scenario.

Actor	Role in scenario	Remarks
GM	(Game manager)	External to scenario; starts and stops simulation, and injects events. Role filled by student researcher (2nd author).
CP	Crisis manager, located in Europe	Superior of PUC1, PUC2, and PUC3. Role filled by Subject 1.
PUC1	Truck convoy	Contracted to crisis management organization for this mission, reporting to the CP. Role filled by Subject 2.
PUC2	Fuel supplier	Contracted to crisis management organization for this mission, reporting to the CP. Role filled by Subject 3.
PUC3	Local representative in Khartoum	Alerts organization to floods, and (in Condition B only) arranges truck repair. Role filled by supervisor (3rd author).

The simulation took the form of a Control Post Exercise (CPX), i.e. only the decision-making function of each unit in the organization was simulated (by filling the actors' roles with human subjects). The sacks of maize, trucks, roads, flooding, fuel, broken water-pump, etc were simulated manually by the appropriate actor. For example, the subject playing the PUC1 role calculated the time it would take for the truck convoy to drive along a given segment of the route, reading the distance off Google Maps, and then sending an e-mail/tweet reporting the convoy's arrival at the (simulated) arrival time. No computer simulation support was provided, i.e. the scenario was "hand-simulated". To run the simulation as fast as possible, actors did not wait a representative amount of ("wallclock") time, but immediately reported their next event ("time-warping").

Interaction between the actors was driven by the following simulated events, triggered by the GM:

- Event 1 (2 days before start, GM to CP): Ship carrying sacks of maize will reach Port Sudan in two days time.
- Event 2 (start of scenario, Friday 04:00 hours, GM to CP): Ship has been unloaded.
- Event 3 (Saturday 06:00 to 10:00 hours, GM to CP): Relief organization's headquarters suffers power failure, and CP cannot receive or send e-mail/tweets. This event was included to stimulate self-synchronization.
- Event 4 (Saturday 06:30 hours, GM to PUC3): Floods have washed away the road at Atbara.
- Event 5 (Condition B only; Sunday 06:00 hours, GM to PUC1): Water-pump on truck has broken (and must be fixed immediately).

The scenario was run twice, once for Condition A and once for Condition B. In Condition A, e-mail was used for communications between the CP and the units in the PUC. While the subjects had access to a large-scale map of Sudan (Figure 3), the positions of PUC units were not marked on it. By contrast, in Condition B the CP plotted the reports received via Twitter on a shared map in CrowdMap (see Figure 4). Tweets differ from e-mail in that they are limited to 140 characters. This limitation had no consequence because NATO-standard abbreviations could be used (e.g. "ETA" carries the same amount of information as "estimated time of arrival"),

although it did prompt one subject to observe that it was important to use clear jargon. More importantly, users can receive tweets in three ways: if the sender explicitly addresses the tweet to the recipient using the "@" notation, if the recipient is a follower of the sender, or if the recipient searches for the tweet by its hashtag. Since the CP, PUC1, PUC2, and PUC3 were all following each other, self-synchronization was facilitated. CrowdMap reinforced this by sharing situation awareness in the form of a map. When one actor posted a report on CrowdMap, this was immediately visible to the other actors.

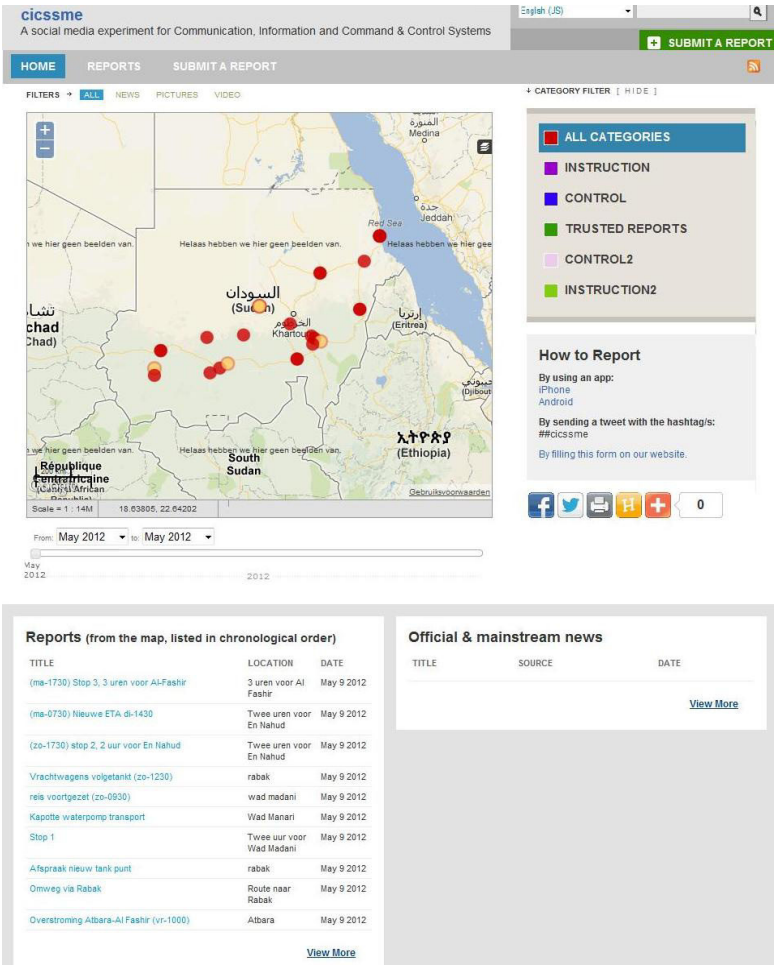

Figure 4. CrowdMap display in use during experiment.

The data collected for analysis comprised the following:

- The GM maintained a logbook of his observations.
- Each subject completed a questionnaire before and after the experiment. See Geugies (2012), Annexes B to D, for details of the questions asked of the three subjects and their answers.
- All communications (e-mail and tweets) were captured as electronic files[4].
- Events within the laboratory were recorded using a video camera.

Performance of Experiment

Human subjects were drawn from the population of officer-cadets at the Netherlands Defence Academy. All were in their early twenties, had around ten years experience of using social media (i.e. were "digital natives"), and were in the third or fourth years of their academic bachelor studies. Prior to these studies, they had all undergone one year's military officer training, including lessons and field exercises on the theory and practice of network-enabled C2. While the subjects did not have real-world operational experience of C2, they did have theoretical and practical knowledge of network-enabled C2. Subjects were selected by their commanding officer

[4] Interested readers may request these files from the second author.

(who was not involved in the experiment) solely on the basis that they had no lecture commitments on the day of the experiment; we regard this as a random process. Subjects 1 and 3 were Twitter users, but none had previously used CrowdMap. Subject 3 had used an operational C2 system that both provides a situation awareness display similar to CrowdMap and has the peer-to-peer and UGC characteristics of social media, but is not implemented using Web 2.0 technology. The GM assigned the subjects to their CP, PUC1, and PUC2 roles, as shown in Table 1.

A classroom was temporarily converted into a laboratory. Each subject had a laptop coupled to the Internet, and e-mail, Twitter, and CrowdMap accounts. In Twitter, the accounts were set up so that each actor was a follower of every other actor. The GM prepared the laboratory, assigned and briefed the subjects, administered the questionnaires, ran the two simulations, and collected and analysed the results.

The experiment took place from 10.00 to 14.30 local time on 9 May 2012. Figure 5 is a still from the video showing the experiment in progress.

Figure 5. Still from video showing experiment in progress.

Results and analysis

The data collected for analysis consisted of six questionnaires (two for each subject), 64 unique e-mails collected during the Condition A run, and 61 unique tweets collected during the Condition B run. Two misaddressed e-mails have been eliminated from the data. The subjects' questionnaire answers are necessarily subjective, but the numerical data collected about the e-mails and tweets is more objective (within the limitations of the experiment). The GM's logbook and video recording were used only for resolving uncertainties in interpreting the questionnaires, e-mails or tweets.

Notable outcomes from the three subjects' questionnaire answers were as follows:

- All three subjects definitely saw value in using social media for C2 purposes. One subject remarked that social media systems would have to be secure.
- One subject noted that social media allowed recipients to read messages that was not specifically addressed to them, and that this had both advantages (e.g. enabling self-synchronization) and disadvantages (e.g. information overload). Another noted that short messaging demanded the use of clear jargon. A third remarked that social media allowed users to gain a better overview.
- While the subject in the CP role gained the impression that the PUCs did not look at CrowdMap, the PUC subjects were positive about CrowdMap's benefits. They could readily see where everything was, and it saved them having to state their location in every tweet.
- None of subjects felt that someone was "looking over their shoulder", and none of them felt the need for one-to-one discussions with another participant.

The numerical data collected included the numbers of messages sent and received by each subject and the simulated times to complete the mission. This data was compared for Condition A and Condition B.

Table 2 compares the numbers of messages sent and received by actor in Conditions A and B. Three noteworthy observations are that:

- The total numbers of messages sent and received in Condition B were less than the corresponding

totals in Condition A, despite Condition B including an extra event (Event 5: broken water-pump).

- The number of messages sent by the CP in Condition B is one-fifth of the number sent in Condition A. By contrast, the numbers of messages the CP receives are not noticeably different.
- Of the three PUCs, PUC1 sends noticeably more messages and receives noticeably fewer messages in Condition B than in Condition A. By contrast, the other two PUCs show little difference.

Table 2. Comparing messages sent and received.

Actor	**Messages sent**		**Messages received**	
	Condition A	**Condition B**	**Condition A**	**Condition B**
CP	24	5	27	23
PUC1	26	37	32	23
PUC2	10	11	17	18
PUC3	4	8	8	9
Totals:	*64*	*61*	*84*	*73*

The first observation deserves more explanation. E-mail recipients only receive e-mails if they have been specifically addressed to the recipient (by the sender including the recipient's e-mail address in the To:, CC:, or BCC: field). Tweets are received either if the recipient is an addressee (as for e-mail) or if the recipient is following the sender. In the experiment, each actor was a follower of every other actor. Hence, all four actors actually saw all 61 tweets sent. In Table 2, the column for Messages received in Condition B shows tweets addressed to the recipient explicitly using the "@" notation.

We looked in more depth at the five tweets sent by the CP in Condition B; see Table 3. Related tweets sent by other actors have been included (in italics) to give the context. We observed that:

- The CP only sends tweets at the start of the scenario (tweets 1, 3, and 5) and mid-way through (tweets 32 and 34).
- The only CP tweet that can be considered as an instruction is tweet 3: "Destination Al Fashir". The other tweets are informative (tweets 1 and 5) or give guidance (tweets 32 and 34).
- The tweet sequence 29 to 31 is a clear example of self-synchronization.

Table 3. Five tweets sent by CP, with related tweets (in italics), grouped into episodes.

No.	Original tweet	Translation into English		
		Sender	Sent to	Content
1	@cicssmecp @cicssmepuc1, @cicssmepuc2, @cicssmepuc3 Schip maïs verwacht over twee dagen in haven Soedan #cicssme 9 mei 12 om 12:52	CP	PUC1, PUC2, PUC3	Ship [carrying] maize expected in harbour in 2 days
2	*@cicssmepuc1 Tijd? @cicssmecp #cicssme 9 mei 12 om 12:53*	*PUC1*	*CP*	*[At what] time?*
3	@cicssmecp @cicssmepuc1 Tijdstip onbekend, lading 40 ton. Bestemming Al Fashir. # cicssme 9 mei 12 om 12:54	CP	PUC1	Time unknown, load 40 tonnes. Destination Al Fashir
5	@cicssmecp @cicssmepuc1 @cicssmepuc2 @cicssmepuc3 Vracht maïs over 1 uur in haven. Los tijd 1 dag. #cicssme 9 mei 12 om 12:58	CP	PUC1, PUC2, PUC3	Freight of maize in harbour in 1 hour. Unloading time [is] 1 day
28	*@cicssmepuc1 Trouble! zo 06:00 waterpomp is stuk kan niet verder! sta bij Wad Manari @cicssmecp #cicssme 9 mei 12 om 13:33*	*PUC1*	*CP*	*Trouble! [At] Sunday 06:00 water-pump is broken [and] cannot proceed! At Wad Manari.*
29	*@cicssmepuc1 Mogelijkheid tot vervangende waterpomp of vrachtwagen? @cicssmepuc3 #cicssme 9 mei 12 om 13:34*	*PUC1*	*PUC3*	*Possibility of replacing water-pump or truck?*

30	*@cicssmepuc3 @cicssmepuc1 @cicssmecp #cicssme kan proberen voor spare part te zorgen. tegen kostprijs. 9 mei 12 om 13:35*	*PUC3*	*PUC1, CP*	*Can try to arrange for spare part. At cost price.*
31	*@cicssmepuc1 @cicssmepuc2 andere ideeën om weer op weg te kunnen?! #cicssme 9 mei 12 om 13:35*	*PUC1*	*PUC2*	*Any other idea to get going again?*
32	@cicssmecp @cicssmepuc1 @cicssmepuc3 Kapotte waterpomp zelf repareren eventueel met hulp PUC3. hoeveel vertraging? #cicssme 9 mei 12 om 13:35	CP	PUC1, PUC3	Repair broken water-pump yourself, perhaps with help from PUC3. How long a delay?
33	*@cicssmepuc1 @cicssmecp extra kosten geen probleem? #cicssme 9 mei 12 om 13:36*	*PUC1*	*CP*	*Extra cost is no problem?*
34	@cicssmecp @cicssmepuc1 Zelf inschatten, geen probleem 9 mei 12 om 13:36	CP	PUC1	Judge for yourself, no problem [from my viewpoint]

The overall simulated time needed to complete the mission, measured from the ship's arrival at Port Sudan to the truck convoy's arrival in Al Fashir, was predicted to be 5 days 5 hours in Condition A and 4 days 8 hours in Condition B. These times were obtained by the GM by hand simulation before the experiment was performed. They do not take account of the effect of learning from Condition A in Condition B, but do assume that self-synchronization occurs from the start in Condition B. The actual times achieved by the three subjects during experimentation were 5 days 5 hours in Condition A (as predicted) and 4 days 6.5 hours in Condition B. The actual time for Condition B is shorter than predicted because PUC1 used Google Maps during the run to find a slightly shorter route than the experimenters had assumed.

In summary, the proof-of-principle experiment succeeded. The use of social media resulted in fewer messages and a shorter time to complete the mission, despite an extra external event. Moreover, the subjects saw definite value in using social media for C2 purposes, although clear jargon and secure systems would be necessary.

CONCLUSIONS AND FURTHER RESEARCH

The literature on the use of social media in crisis response and management is largely concerned with communication between organizations and citizens. By contrast, this paper describes an experiment designed to test whether social media can be used internally within crisis response organizations for Command & Control (C2) purposes. The laboratory experiment was performed with human subjects modelling the operational units and a control centre in a simulated famine relief scenario. There were two experimental conditions: e-mail was used in Condition A, and Twitter and CrowdMap were used in Condition B. Despite an extra event in Condition B, the simulated mission was completed in a shorter (simulated) time in Condition B with fewer messages sent and received. As intended, self-synchronization emerged early, but could only be exploited fully using social media (Condition B). The number of messages sent by the control centre (CP) in Condition B was one-fifth of the number sent in Condition A. Moreover, the centre's role changed from giving instructions to giving advice and guidance.

Given that the experiment was performed within the context of a bachelor student's capstone project, time and resources were strictly limited. This lead to two key limitations in the research reported here. Firstly, the experiment could not be replicated with many different sets of subjects, but could only be performed once. Secondly, the same set of subjects ran Condition A followed by Condition B, leading to the strong possibility that they benefited from learning. To counter the confounding effect of learning, we added an extra external event to Condition B. Nevertheless, Condition B was performed in less (simulated) time with less messages.

Despite its limitations, the prime contribution of this paper is that it has proven the principle expounded in Jongejan and Grant (2012). The application of social media technology to the control loop in a laboratory experiment can enhance self-synchronization between (simulated) First Responders, resulting in the faster achievement of the mission. On this basis, we conclude that further research is warranted. In particular, this result should stimulate other researchers to initiate more detailed and comprehensive Concept Development & Experimentation (CD&E), possibly leading eventually to operational applications of social media in C2.

ACKNOWLEDGMENTS

We thank an anonymous reviewer for drawing our attention to Yates and Paquette (2011) and for raising a range of issues that will undoubtedly have sharpened this paper. The second author thanks Helmuth Jansen, Peter Jongejan, Herjan Kerkdijk, Joy Mangroelal, and Evelien Sluiter for their participation in the experiment.

REFERENCES

1. Alberts, D.S. & Hayes, R.E. (2003) Power to the Edge: Command control in the information age. US Department of Defense Command & Control Research Program.
2. Ashby, W.R. (1956) Introduction to Cybernetics. London: Methuen.
3. Boekhout, T. (2012) Private communication to 3rd author, 16 November 2012.
4. Denis, L.A.S., Hughes, A.L., & Palen, L. (2012) Trial by Fire: The Deployment of Trusted Digital Volunteers in the 2011 Shadow Lake Fire." *Proceedings of the 9th International Conference on Information Systems for Crisis Response And Management* (ISCRAM 2012), Vancouver, Canada.
5. Endsley, M.R. (1988) Design and Evaluation for Situation Awareness Enhancement. *Proceedings of the 32nd annual meeting of the Human Factors Society*, Santa Monica, CA, 97-101.
6. Geugies, F.L.E. (2012) Sociale Media in Commandovoering: "Proof of principle". Unpublished bachelor dissertation, Faculty of Military Sciences, Netherlands Defence Academy, 5 July 2012. [In Dutch: Social Media in Command & Control: Proof of principle].
7. Jongejan, P.A. & Grant, T.J. (2011) A Refined Framework for Crisis Management Communication via Social Media. In Loos, E.F. & Meijer, A.J. (eds.), *Proceedings of the 8th annual work conference of the Netherlands Institute of Government* (NIG 2011), Rotterdam, The Netherlands, 1st-2nd December 2011, panel 11 ("Using Social Media in the Public Domain: A mission impossible?].
8. Jongejan, P.A. & Grant, T.J. (2012) Social Media in Command & Control: An extended framework. *Proceedings of the 9th International Conference on Information Systems for Crisis Response And Management* (ISCRAM 2012), Vancouver, Canada.
9. Kaplan, A.M. & Haenlein, M. (2010) Users of the World, Unite! The Challenges and Opportunities of Social Media. *Business Horizons*, 53, 59-68.
10. Kietzmann, J.H., Hermkens, K., McCarthy, I.P., & Silvestre, B.S. (2011) Social Media? Get Serious! Understanding the Functional Building Blocks of Social Media. *Business Horizons*, 54, 241-251.
11. Mankins, J.C. (1995) Technology Readiness Levels: A white paper. NASA, Office of Space Access and Technology, Advanced Concepts Office. Downloaded from http://www.hq.nasa.gov/office/codeq/trl/trl.pdf, accessed 15 February 2013.
12. Manso, M. & Manso, B. (2012) The Role of Social Media in Crisis: A European holistic approach to the adoption of online and mobile communications in crisis response and search and rescue efforts. *Proceedings of the 17th International Command & Control Research & Technology Symposium* (ICCRTS 2012), June 2012, Fairfax, VA.
13. Reuter, C., Marx, A., & Pipek, V. (2011) Social Software as an Infrastructure for Crisis Management: A case study about current practice and potential usage. *Proceedings of the 8th international conference on Information Systems for Crisis Response And Management* (ISCRAM 2011), May 2011, Lisbon, Portugal.
14. Starbird, K. & Stamberger, J. (2010). Tweak the Tweet: Leveraging Microblogging Proliferation with a Prescriptive Syntax to Support Citizen Reporting. *Proceedings of the 7th International Conference on Information Systems for Crisis Response and Management* (ISCRAM 2010), May 2010, Seattle, USA.
15. US DoD. (2011) Dictionary of Military Terms and Abbreviations. Joint Publication 1-02, US Department of Defense, Washington DC.
16. Vieweg, S., Palen, L., Liu, S.B., Hughes, A. L. & Sutton, J. (2008). Collective Intelligence in Disasters: Examination of the phenomenon in the aftermath of the 2007 Virginia Tech shooting. *Proceedings of the 5th International Conference on Information Systems for Crisis Response and Management* (ISCRAM 2008), Washington D.C., USA.
17. Wikipedia. (2013) Proof of Concept. Downloaded from http://en.wikipedia.org/wiki/Proof_of_concept, accessed 11 February 2013.
18. Yates, D. & Paquette, S. (2011) Emergency Knowledge Management and Social Media Technologies: A case study of the 2010 Haitian earthquake. *International Journal of Information Management*, 31, 6-13