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REVIEW ARTICLE



Cognition in crisis management teams: an integrative analysis of definitions

Jukrin Moon^a , Farzan Sasangohar^a , Changwon Son^a  and S. Camille Peres^b 

^aDepartment of Industrial and Systems Engineering, Texas A&M University, College Station, TX, USA; ^bDepartment of Environmental and Occupational Health, Texas A&M University, College Station, TX, USA

ABSTRACT

In large-scale extreme events, multidisciplinary crisis management teams (CMTs) are required to function together cognitively. Despite theoretical maturity in team cognition and recurrent emphasis on cognition in the crisis management practices, no synthesis of theoretical and practical discourses is currently available, limiting empirical investigations of cognition in CMTs. To address this gap, this paper aims to review the definitions of cognition in CMTs, with a particular focus on examining if and to what extent they are diversified. Through a systematic process to search peer-reviewed journal articles published in English from 1990 to 2019, 59 articles were selected with 62 coded definitions of 11 different constructs. The similarities and variabilities of the definitions were examined in terms of their theoretical and practical emphases and then synthesised into an integrative definition expected to serve as a general guide of reference for future researchers seeking an operational definition of cognition in CMTs.

Practitioner summary: Understanding of cognition in CMTs is grounded in various theories and models with varying assumptions. An integrative conceptualisation of such cognition as interaction within and across CMTs to perceive, diagnose, and adapt to the crisis may facilitate the accumulation of knowledge and future operationalisations.

Abbreviations: CMT(s): crisis management team(s); SMM: shared mental model; TMM: team mental model; COP: common operating picture; SSA: shared situation awareness; TSA: team situation awareness; DC: distributed cognition; ITC: interactive team cognition; TMS: transitive memory system(s); DSA: distributed situation awareness

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Team cognition; crisis management; multi-team; common operating picture; collective sensemaking

1. Introduction

Timely and effective management of catastrophic events, natural or human-made, has become increasingly important. Annual economic losses incurred by natural disasters worldwide were over \$300 billion in 2017 (United Nations Office for Disaster Risk Reduction 2019). Between 1980 and 2019, the United States has experienced several weather events resulting in the total cost of over \$1.7 trillion (in 2019 dollars) (National Oceanic and Atmospheric Administration 2019). Due to continuing changes in climate, the frequency and severity of extreme events are forecasted to keep increasing (Intergovernmental Panel on Climate Change 2012).

When an extreme event takes place, crisis management teams (CMTs) are quickly established to respond to and provide recovery from the event. Although CMTs, involving multiple disciplines such as firefighting,

law enforcement, and emergency medical service, may have limited experience working together, they are charged to meet urgent and dynamic demands as quickly and effectively as possible. Coordinating efforts within and across multidisciplinary CMTs are essential to making crisis management operations effective (Bigley and Roberts 2001; Uitdewilligen and Waller 2018); however, such coordination may impose challenges mainly due to the complexity of information exchange mechanisms at various levels (e.g., federal, state, local), especially under elevated uncertainty and time pressure (Bharosa, Lee, and Janssen 2010; Militello et al. 2007). For example, in response to the 9/11 terrorist attacks, 229 public, 160 private, and 67 non-profit organisations processed information interdependently and dynamically, through inter-organisational and inter-jurisdictional coordination (Comfort 2002; Comfort and Kapucu 2006). Such complexity may result in breakdowns in coordination within and across CMTs, which

may lead to substantial consequences such as delayed response and increased casualties (Comfort 2007; DeChurch and Zaccaro 2010; Grunwald and Bearman 2017).

Cognition plays a key role in the functioning of crisis management and, in particular, dynamic coordination among resources. Cognition, in the crisis management context, is defined as “the capacity to recognize the degree of emerging risk to which a community is exposed and to act on that information” (Comfort 2007, 189). Indeed, team cognition has been studied as a coordinating mechanism in disaster response (see Fiore and Salas 2004). Investigations of several disasters (e.g., the Three Mile Island, 1979; the Chernobyl nuclear power plant, 1986; the Space Shuttle Challenger, 1986) have shown that team coordination and performance deteriorate under cognitively demanding environments (Cooke, Gorman, and Winner 2008). DeChurch and Mesmer-Magnus (2010) posited that such findings had fostered sustained efforts to explore whether cognition of a team contributes to the team’s coordination and performance across multiple safety-critical disciplines, including crisis management, military command and control, aviation, process control, and healthcare.

Cognition in a team environment has been conceptualised using two dominant theories in the literature: knowledge-based cognition and interaction-based cognition (Wildman, Salas, and Scott 2014). Knowledge-based cognition theory’s advocates argue that a team should function as an aggregated group of individuals with shared (i.e., overlapping and/or distributed) knowledge structures (Cannon-Bowers & Salas 2001; Mohammed, Ferzandi, and Hamilton 2010). Under this school of thought, a construct such as a shared mental model or team mental model (Cannon-Bowers, Salas, and Converse 1990) describes how team members’ mental representations overlap. On the other hand, the interaction-based cognition theory’s proponents claim that such overlap between mental models may lack practical relevance (without explaining the role of interactions to achieve it) to real-world teams which are becoming larger, more heterogeneous, dynamic, and interdependent (Salas, Cooke, and Rosen 2008). The interaction-based cognition theorists claim that interactive team cognition (Cooke et al. 2013) can only be formed through timely interactions between different team members with specified but complementary tasks, assuming that a team will fail to achieve its goals otherwise. Other constructs such as shared situation awareness or team situation awareness (Saner et al. 2009) and transactive

memory system (Wegner 1987) view both knowledge and interaction as necessary elements for better cognition of teams. Beyond the scope of team cognition research, other cognition-related constructs have also been theorised for the practical application to such a real-world team or multi-team environment (Shuffler, Jiménez-Rodríguez, and Kramer 2015).

Despite the recurrent emphasis on the role of macro-level cognition in crisis management practices, the literature on this topic has been fragmented, and no synthesis of theoretical and practical discourses is currently available to inform future research in this area. To address this gap, this paper reviews the definitions of cognition in CMTs. Our particular focus is on examining if and to what extent the definitions are diversified, for the ultimate goal of providing an integrated and convergent view. We expect that our synthesis and the resulting integrated view will empower researchers to evaluate various interpretations and theories of cognition applied to CMTs and facilitate the aggregation of knowledge in this field.

2. Method

A literature review was conducted to compile and synthesise knowledge related to cognition in CMTs. To develop search and selection as well as data extraction and analysis protocols, two systematic review librarians at Texas A&M University were consulted.

2.1. Search and selection protocols

We searched CINAHL, Compendex, MEDLINE (Ovid), and PsycINFO using subject and text-word search

Table 1. Controlled search terms related to the two subjects of interest for each of the four chosen databases.

Database	Controlled terms: <i>crisis management</i>	Controlled terms: <i>cognition in teams</i>
CINAHL	Disaster management Disaster planning Disasters Emergencies Emergency service Natural disasters	Cognition Group processes Teamwork
Compendex	Disasters Disaster prevention Emergency services	Cognitive systems
MEDLINE (Ovid)	Disaster planning Disasters Emergencies Natural disasters	Cognition Group processes
PsycINFO	Crises Disasters Emergency management Emergency services Natural disasters	Cognition Group decision making Intergroup dynamics

Table 2. Free-text search terms related to the four target keywords.

Free-text terms: <i>crisis</i>	Free-text terms: <i>manage</i>	Free-text terms: <i>teams</i>	Free-text terms: <i>cognition</i>
disaster* cris* emergenc* incident*	command* collaborat* coordinat* manag* mitigat* operat* plan* prepar* recover* respon*	interteam* inter-team* multiteam* multi-team* team*	cogniti* information process* information shar* interactive cognition* mental model* sensemak* sense-making* situation* awareness* strategic consensus* transactive memory system*

Note: *for truncation.

strategies (Jenuwine and Floyd 2004). For subject search strategy, we developed a set of controlled (indexed) search terms for each of the four databases, considering their indexing differences (Table 1). Controlled terms were based on relevance to either 'crisis management' or 'cognition in teams'.

For the text-word search, we developed a set of free-text (non-indexed) search terms for each of the following four keywords and their relata: 'crisis', 'management', 'teams', and 'cognition' (Table 2). Our choice of free-text terms was based on their relevance to the four keywords as well as the authors' experience and findings from previous literature (DeChurch and Zaccaro 2010; Wildman, Salas, and Scott 2014). To represent the keyword 'cognition', for instance, we incorporated the five most frequently referenced constructs to measure cognition in teams, i.e., (team) mental model, transactive memory system*, (team) situation* awareness, interactive (team) cognition, and strategic consensus (see Wildman, Salas, and Scott 2014). Table 3 presents the exact search strings used for PsycINFO.

The initial search was restricted to English-language peer-reviewed journal articles published between 1990 and 2019. Although major attention on cognition in crisis management was raised in hindsight of Hurricane Katrina (Comfort 2007), our scope of the search was further broadened to embrace earlier attention on team cognition following several disasters prior to 1990. Forward and backward search was also conducted to identify secondary sources referenced in or citing the identified papers. The initial search yielded 2,071 articles, 424 of which were identified as duplicates and removed using Rayyan (Ouzzani et al. 2016).

Title and abstract screening excluded review articles; discussions of crises less relevant to the management of disastrous events (e.g., acute patient care, business, emotional, financial, mental health,

Table 3. Search strings used for PsycINFO.

Search ID	Search Query	Results
S1	MA Crises OR MA Disasters OR MA Emergency management OR MA Emergency services OR MA Natural disasters	7,345
S2	MA Cognition OR MA Group decision making OR MA Intergroup dynamics	73,531
S3	S1 AND S2	88
S4	disaster* OR cris* OR emergenc* OR incident*	168,888
S5	command* OR collaborat* OR coordinat* OR manag* OR mitigat* OR operat* OR plan* OR prepar* OR recover* OR respon*	1,680,825
S6	interteam* OR inter-team* OR multiteam* OR multi-team OR team*	88,977
S7	cogniti* OR information process* OR information shar* OR interactive cognition OR mental model* OR sensemak* OR sense-making OR situation* awareness OR strategic consensus OR transactive memory system*	804,560
S8	S4 AND S5 AND S6 AND S7	582
S9	S3 OR S8	665
S10	S3 OR S8 (Publication Year: 1990–2019; Publication Type: Peer Reviewed Journal; Language: English)	439

Note: * for truncation. MA for MeSH subject heading.

organisational, sports, and surgery crises); studies on units other than teams or multiteams (e.g., individuals, computing systems, or infrastructures); and constructs less relevant to cognition in teams or multiteams (e.g., team psychological safety, team moral atmosphere, cognitive empathy, leadership, leader sensemaking, or stress). Remaining full texts were assessed by two independent coders to check if the articles met inclusion criteria: eligible studies must study cognition (a) in teams or multiteams, (b) working in the context of disastrous events, (c) as a core construct, and (d) with an explicit definition. The two coders met to discuss the eligibility criteria prior to independent full-text reviews, and their resulting intercoder reliability ($\kappa = .84$) was interpreted as substantial (McHugh 2012).

After applying the exclusion and inclusion criteria to the title/abstract screening and full-text assessment, 59 articles were selected for the final review. Figure 1 depicts the overall literature search and selection process utilising the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines (Moher et al. 2009).

2.2. Data extraction and analysis protocols

Data extraction sought core cognitive constructs and definitions. Direct quotes of the definitions were manually extracted and entered into a spreadsheet along with their associated constructs and bibliographic data (i.e., authors, published year, and extracted page numbers). As some articles contained multiple definitions, a total of 62 definition instances were collected from the selected 59 articles.

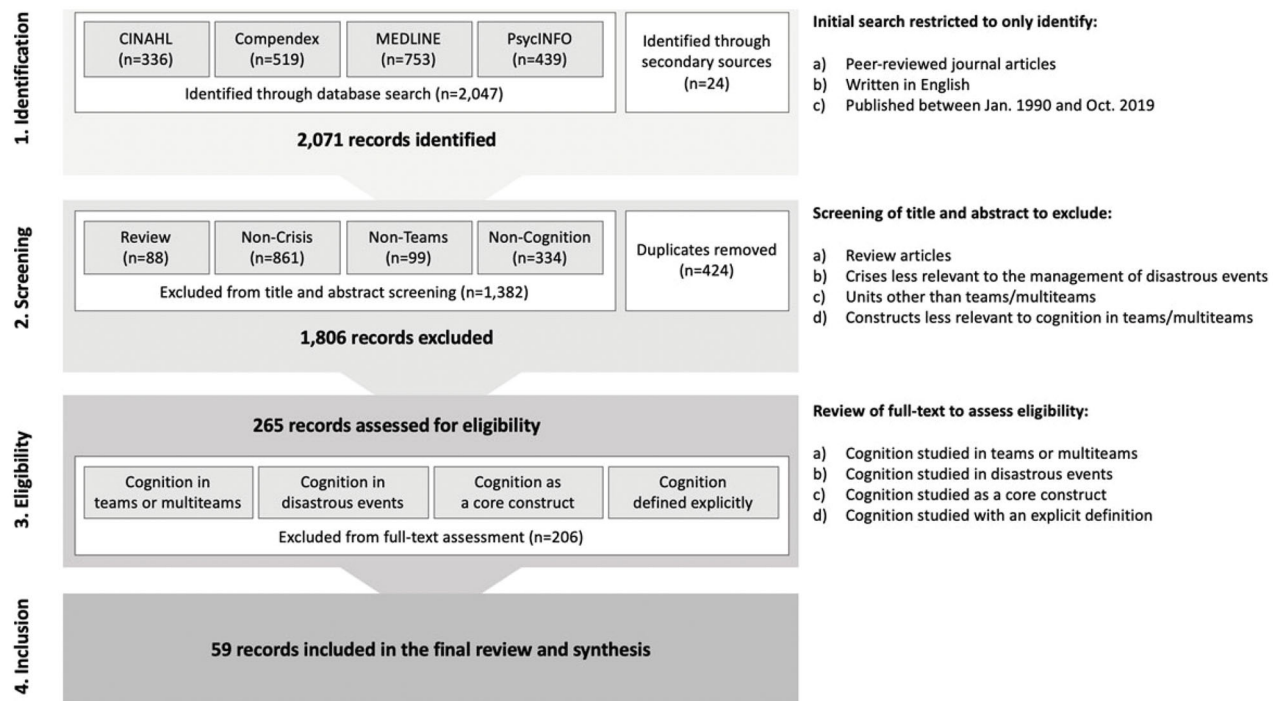


Figure 1. Literature search and selection process using the PRISMA guidelines.

Table 4. Three dimensions of analysis and their categories.

Dimensions of analysis	Categories
(a) Associated construct	–
(b) Theoretical assumption(s)	Knowledge-based cognition Interaction-based cognition Both
(c) Unit of analysis	Team (conceptualising intra-team cognition in a CMT) Multiteam (conceptualising intra- and inter-team cognition in a system of CMTs)

We assessed each of the 62 definitions across three dimensions of analysis selected for the purpose of synthesising similarities and variabilities: (a) associated construct; (b) underlying theoretical assumption(s), i.e., knowledge-based and/or interaction-based cognition; and (c) unit of analysis, i.e., cognition in a team or a multiteam (Table 4). The first and second dimensions were adopted to follow the way team cognition measures have been assessed in previous reviews (e.g., Mohammed, Ferzandi, and Hamilton 2010; Mohammed et al. 2015; Wildman, Salas, and Scott 2014). After recording the associated construct applied to define cognition in CMTs, we qualitatively assessed the theoretical assumption(s) based on the question: Is cognition in CMTs “being conceptualized as the content or structure of knowledge, [and/]or as team interaction?” (p.931, Wildman, Salas, and Scott 2014). We applied the first and second dimensions to not only a CMT but also a system of CMTs. As reflected in free-text search terms such as *interteam** and *multiteam** as well as *team** (Table 2), we interpreted ‘teams’ in a

broad sense to incorporate crisis management considerations into our scope of analysis (e.g., Bharosa, Lee, and Janssen 2010; DeChurch and Zaccaro 2010; Militello et al. 2007; Wolbers and Boersma 2013). As such, we additionally selected the third dimension, i.e., unit of analysis, and examined the extent to which the first- and second-dimensions’ assessment differs across the third dimension. Lastly, we synthesised the similarities and variabilities across the three dimensions of analysis to develop an integrative definition.

3. Results and discussion

3.1. An overview of the definitions

Overall, we found large variability in the constructs applied to define cognition in CMTs. A total of 11 constructs were identified from 62 definition instances (see D1-D62 in Tables 5–15) with significant intercoder reliability ($\kappa = .84$) as follows: collective sensemaking ($n = 13$), shared/team mental model (SMM/TMM;

Table 5. Definitions of collective sensemaking in CMTs ($n = 13$).

Definition ID	Authors (year)	Definitions of collective sensemaking in CMTs
D1	(Weick 1993, 635–636)	“Reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs.”
D2	(Landgren 2005, 179)	“When people are surprised or when they experience that expected event does not occur, they direct their conversation to clarify the blurred and confusing picture – to make sense.”
D3	(Bergeron and Cooren 2012, 121)	“A way a team perceives the situation at hand and how it collectively defines and make sense of the situation.”
D4	(Wolbers and Boersma 2013, 188–189)	“Combining different cues, roles, scripts, and actions that arise from the actors’ different institutional backgrounds ... into a collaborative time critical response”
D5	(Wu et al. 2013, 6–7)	“[Finding] critical patterns in a seemingly unstructured situation by developing successively more sophisticated representations and fitting information into these representations in service of a task.”
D6	(Malakis and Kontogiannis 2014, 213)	“The coordination of practitioners as they seek data, synthesise and disseminate their inferences in a team environment.”
D7	(Benamrane and Boustras 2015, 50)	“The interaction and communication between individuals ... [and] stories and narratives, i.e. the symbolic presentation of a sequence of events connected by subject matter and related by time.”
D8	(Giordano et al. 2017, 181)	“The mechanism allowing the different actors to interpret their environment, to achieve a satisfactory shared understanding of the situation.”
D9	(Takeda, Jones, and Helms 2017, 792)	“The sum of a group of related individuals using their expertise and perceptions to make sense of the disaster environment and respond appropriately.”
D10	(Uitdewilligen and Waller 2018, 732–741)	“Interpretive communication sequences ... whereby team members build on, correct, or add to the situation comprehension of other team members.”
D11	(Waring et al. 2018, 611–612)	“Provid[ing] a rationale for why information is being requested or shared can both speed up access to and encourage attention to be paid to relevant information.”
D12	(Wolbers, Boersma, and Groenewegen 2018, 18)	“Processes in which they retrospectively make sense of events, resulting in a multiplicity of interpretations.”
D13	(Mirbabaie and Marx 2020, 1)	“An endeavour to create meaning in highly uncertain situations ... [and] the process behind assembling pieces of information to create meaning.”

Table 6. Definitions of SMM/TMM in CMTs ($n = 11$).

Definition ID	Authors (year)	Definitions of SMM/TMM in CMTs
		(a) SMM in CMTs
D14	(Smith and Dowell 2000, 1155)	“A degree of consistency between the various mental models of the disaster held by different individual”
D15	(Waller, Gupta, and Giambatista 2004, 1536)	“A mechanism whereby humans generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states”
D16	(Carter and French 2006, 409)	“A common world view shared by a group of people or management team ... [with] three functions: description, explanation and prediction”
D17	(Schraagen et al. 2010, 118–120)	“Being able to share domain-specific knowledge among team members”
D18	(Owen et al. 2013, 6)	“A multi-dimensional construct that enables team members to have more accurate expectations and a compatible approach for task performance”
D19	(Liu et al. 2015, 38)	“Improving awareness of the team task – that is, how the task was organised, represented, and distributed”
D20	(Steinke et al. 2015, 24–25)	“Shared expectations about what information should be given and received”
D21	(Norris et al. 2019, 3–4)	“A shared knowledge of “what time it is” (and what day and date it is), as well as the capacity of people to act on that knowledge in a synchronised way, in due time, or across locally distributed groups”
		(b) TMM in CMTs
D22	(van Santen, Jonker, and Wijngaards 2009, 350–351)	“A representation of the negotiation attitude and negotiation strategy of the individual team member (as well as his/her perception of the negotiation attitudes and negotiation strategies of the other team members)”
D23	(Mohammed et al. 2015, 693–696)	“Agreement among group members concerning deadlines for task completion, the pacing of speed of activities, and the sequencing of tasks”
D24	(Uitdewilligen, Rico, and Waller 2018, 1114–1116)	“A similar understanding among the team members about the central aspects of the task ... developed through team member interaction and interchange of information”

$n = 11$), common operating picture (COP; $n = 10$), shared/team situation awareness (SSA/TSA; $n = 8$), distributed cognition (DC; $n = 5$), interactive team cognition (ITC; $n = 4$), transactive memory systems (TMS; $n = 3$), distributed situation awareness (DSA; $n = 3$), macrocognition in teams ($n = 2$), shared belief ($n = 2$),

and team metacognition ($n = 1$). Each of the 11 constructs is summarised in the following subsections.

3.1.1. Collective sensemaking

Collective sensemaking expands the meaning of sense-making, an individual-based parent term originated

Table 7. Definitions of COP in CMTs ($n = 10$).

Definition ID	Authors (year)	Definitions of COP in CMTs
D25	(Carver and Turoff 2007, 36)	(a) Common as Sameness "A manipulable visualisation of what is happening and where resources are that is open to all members of the emergency management team"
D26	(McMaster and Baber 2012, 45)	"A single representation of relevant incident information that could be shared across service command centres during a multi-agency response"
D27	(Luukkala and Virrantaus 2014, 191–194)	(b) Common as Complementary "An [operational picture] shared by more than one actor/party in a particular operation ... enabl[ing] all the actors/parties to achieve and share situational information in a geographically distributed environment ... [supporting] the different task and goals of different individuals or teams"
D28	(Bunker, Levine, and Woody 2015, 52)	"Appropriat[ing] elements of operational systems from multiple organisations or entities in order to build a shared picture of a disaster situation or extreme event ... [and] to view multiple representations of the same phenomenon"
D29	(Ehnis and Bunker 2020, 1)	"Shar[ing] a common view within an organisation and across involved organisations"
D30	(Comfort 2007, 191–193)	(c) Common as Trading Zone "[A way to] achieve a sufficient level of shared information among the different organisations and jurisdictions participating in disaster operations at different locations, so all actors readily understand the constraints on each and the possible combinations of collaboration and support among them under a given set of conditions"
D31	(Baber et al. 2013, 889)	"Not simply to provide a mechanism to have 'everyone singing from the same hymn-sheet' ... , but also as a means to support collaborative working (in terms of enabling procedures to overlap and interoperate effectively), to improve understanding of risk in the situation of incident-relevant information that could be shared between agencies during a multi-agency response"
D32	(Wolbers and Boersma 2013, 188–189)	"A platform that allows experts to coordinate and negotiate their plurality of points of view through general procedures of exchange, without making their perspectives uniform or completely transparent to each other. ... Not an 'information warehouse' but a form of materiality that facilitates the ongoing negotiation process that takes place in a 'trading zone', in which actors share and give meaning to information to synchronise their actions"
D33	(Steigenberger 2016, 62)	"Communication involves the exchange of information as an attempt to develop a continuously updated [COP] as a basis for coordination and decision-making."
D34	(Tatham, Spens, and Kovács 2017, 84)	"Go[ing] beyond the concept of a data warehouse, and move towards a situation in which the individual actors share their expertise and exchange ideas, learn from one another and make sense of each other's position and institutional background"

Table 8. Definitions of SSA/TSA in CMTs ($n = 8$).

Definition ID	Authors (year)	Definitions of SSA/TSA in CMTs
D35	(Seppänen et al. 2013, 1)	(a) SSA in CMTs "A shared understanding of that subset of information that is necessary for each of their goals"
D36	(Seppänen and Virrantaus 2015, 113)	"The degree to which team members have the same SA on [SSA] requirements"
D37	(Valaker, Haerem, and Bakken 2018, 425)	"The degree to which all the team members accurately know the information required to reach the goals and subgoals associated with their joint task"
D38	(Kaber and Endsley 1998, 44–45)	(b) TSA in CMTs "The degree to which every team member possesses SA on these elements for task performance ... [The one existing] among teams which are distributed spatially or temporally [is] inter-team SA (versus intra-team SA or SA within a single team)"
D39	(Son, Aziz, and Peña-Mora 2008, 422)	"A shared understanding of a situation among team members at a particular point in time"
D40	(Schraagen and van de Ven 2011, 180)	"SA of the overall team is constituted by team member interactions ... [F]ocusing on team processes, [TSA] does not assume complete overlap in knowledge"
D41	(Luukkala and Virrantaus 2014, 191–194)	"... [TSA] does not mean that every team member needs to have a high level of SA about everything, but they do need to have a high level of SA about the factors that are relevant for their tasks."
D42	(van de Walle, Brugghe-mans, and Comes 2016, 68)	"The degree to which every team member possesses the situation awareness required for her or his responsibilities"

Table 9. Definitions of DC in CMTs ($n = 5$).

Definition ID	Authors (year)	Definitions of DC in CMTs
D43	(Furniss and Blandford 2006, 1174–1177)	"A framework for understanding team working; A view on how information is transformed and propagated around a system"
D44	(Toups, Kerne, and Hamilton 2011, 23:3)	"Cognitive processes spread among individuals and artefacts as they mutually interact; A framework for analysing information processing within teams and modelling the way in which information flows among participants and artefacts over time"
D45	(Plant and Stanton 2014, 779)	"The process by which multiple individuals or teams work together in pursuit of a common goal which is comprised of multiple interacting sub-goals"
D46	(Plant and Stanton 2016, 1353)	"Cognitive processes distributed in three ways; socially across team members, distributed across internal and external information and distributed through time such that products of earlier events can transform the nature of later events"
D47	(Rybing et al. 2016, 424)	"A sociotechnical framework that emphasises how such workplace arrangements facilitate collaboration and cognition"

Table 10. Definitions of ITC in CMTs ($n = 4$).

Definition ID	Authors (year)	Definitions of ITC in CMTs
D48	(Stachowski, Kaplan, and Waller 2009, 1537)	"Regular sets of verbalizations and nonverbal actions intended for collective action and coordination"
D49	(Pfaff 2012, 560)	"The information processing activities of a team; The interplay between cognitive processes happen[ing] socially, rather than solely within the mind of an individual"
D50	(Uitdewilligen and Waller 2018, 732–741)	"Communication involving the introduction of members' individually held knowledge into the team's public space; The exchange of privately held information about the task situation with the other members of the team; Team information sharing behaviours pertaining to the three levels: fact sharing, interpretation sharing, and projection sharing"
D51	(Gorman et al. 2019, 1, 4)	"The ability to adaptively reorganise team coordination processes, in response to novel or challenging events ... [by understanding] how the individual-level inputs and team-level dynamics become intertwined by tracking how teams reorganise in response to changing task demands and unexpected perturbations"

Table 11. Definitions of TMS in CMTs ($n = 3$).

Definition ID	Authors (year)	Definitions of TMS in CMTs
D52	(Majchrzak, Jarvenpaa, and Hollingshead 2007, 151)	"A shared system for encoding, storing, retrieving, and communicating information that develops naturally in relationships and groups"
D53	(van der Haar, Jehn, and Segers 2008, 204–205)	"A form of collective cognition of groups developed by a process of accumulation, interaction, examination and accommodation ... The basic ingredient is information, and the basic process is information sharing"
D54	(Marques-Quinteiro et al. 2013, 5)	"A shared cognitive system that combines each member's memory system with a shared understanding of which members know, and are responsible for, what knowledge"

Table 12. Definitions of DSA in CMTs ($n = 3$).

Definition ID	Authors (year)	Definitions of DSA in CMTs
D55	(Heard et al. 2014, 65)	"Activated knowledge for a specific task, at a specific time within a system"
D56	(Curnin et al. 2015, 304)	"[DSA] is applicable to strategic level emergency operations centres as each agency's awareness is unique but complementary (not shared) and thus each of the liaison officers are instrumental in the development and maintenance of other agencies situation awareness"
D57	(Fleștea et al. 2017, 45–46)	"A compilational emergent state that describes the task-related knowledge that becomes activated within the MTS at a particular time, and it is necessary for performing the goal directed. The emergence of [MTS SA] is largely dependent on the quality of individual representations acquired through the monitoring of the environmental changes, but also on the intra and inter-team communication processes and leadership."

from the context of crisis management, to team- or multiteam-level. Weick (1993), in his retrospective scrutiny of Mann Gulch fire in 1949, argued that a wildfire crew's breakdown in making sense of unanticipated

situations had led to the tragic loss of 12 smokejumpers. Collective sensemaking in CMTs is one of the most commonly used constructs and has been commonly defined as a collaborative storytelling process via

Table 13. Definitions of Shared belief in CMTs ($n = 2$).

Definition ID	Authors (year)	Definitions of shared belief in CMTs
D58	(Saetrevik and Eid 2014, 123)	"A team's average similarity index may be seen as a measure of the team's SMM and an indicator of the team's average degree of SSA, where high similarity index scores indicate a well-functioning team with good information flow that is facilitated by an efficient team leader"
D59	(Saetrevik 2015, 119)	"The similarity of a team member's beliefs to her or his team leader's beliefs will be used as a proxy for having accurate beliefs about the work and the team, which should correspond to high levels of SA"

Table 14. Definitions of macrocognition in CMTs ($n = 2$).

Definition ID	Authors (year)	Definitions of macrocognition in CMTs
D60	(Handley and Heacox 2010, 376)	"The cognitive processes that occur within collaborative teams in operational settings; The internalised and externalised high-level mental processes employed by teams to create new knowledge during complex, one-of-a-kind, collaborative problem solving"
D61	(Alison et al. 2015, 297–298)	"The study of how teams move between internalisation and externalisation of cognition to build knowledge in service of problem solving. It considers both social and technical influences on team cognition during the decision process to increase understanding of collective group cognition during sense making."

Table 15. Definitions of team metacognition in CMTs ($n = 1$).

Definition ID	Authors (year)	Definition of team metacognition in CMTs
D62	(McLennan et al. 2006, 34)	"Core team members' knowledge of the current states and processes of the team in relation to those states and processes required for the team's goals to be achieved, and their ability to control and modify these team states and processes"

interactive activities of combining incoming information, clarifying any ambiguity or confusion, and making sense of the situation (see Table 5).

3.1.2. Shared mental model (SMM) or team mental model (TMM)

SMM/TMM expands the meaning of mental models ("mental representations of objects, actions, situations or people"; Langan-Fox et al. 2004, 333) to team-level. SMM/TMM in CMTs has been generally defined as the sharing of taskwork-, teamwork-, and/or temporal-knowledge. SMM and TMM in CMTs interpret sharing with two different emphases, i.e., sharing to maximise the 'overlap' between team members' knowledge and sharing to 'distribute' the knowledge among team members (see Table 6). Such knowledge-sharing enables team members' expectations of disaster scenarios to be accurate and/or similar, and their crisis management approaches to be compatible in terms of what to do (taskwork-knowledge), how to do it with whom (teamwork-knowledge), and when to do it (temporal-knowledge). The definitions of SMM/TMM in CMTs acknowledge the importance of communication processes to share knowledge yet do not explicitly explain the role of communication within and across CMTs.

3.1.3. Common operating picture (COP)

COP, a term originated from the context of military command and control, refers to a single integrated display of the current situational information to be shared with geographically distributed actors. Despite its prevalent usage in the crisis management field, the conception of COP in CMTs is predicated upon a mixture of theoretical premises (either as knowledge or interaction) due to three different interpretations of the word, 'common'. First, COP in CMTs implies a 'single', 'integrated', 'overlapping', or 'same' operating picture. Second, COP in CMTs, as opposed to the integrated picture, means a 'distributed', 'divided', or 'complementary' operating picture. While still assuming a knowledge-based perspective, the second interpretation acknowledges the fact that the knowledge "pie" needs to be divided up among heterogeneous teams or team members (Bunker, Levine, and Woody 2015). Third, COP in CMTs indicates an 'open' opportunity, a 'platform' or a 'trading zone' for interaction, rather than a warehouse or a repertoire of knowledge (see Table 7).

3.1.4. Shared situation awareness (SSA) or team situation awareness (TSA)

SSA/TSA expands the meaning of situation awareness (SA) to team-level. SA has been defined with both

knowledge- and interaction-based assumptions, as a state of activated knowledge (i.e., “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 1995, 36) or an appropriate action in response to changes (i.e., “continuous perception-action process in which ongoing activity plays an integral role in what there is to be perceived”, Gorman, Cooke, and Winner 2006, 1314). As shown in Table 8, SSA/TSA in CMTs has been generally defined as the sharing of dynamic SA requirements under both knowledge- and interaction-based assumptions. While SSA (“the degree to which team members possess the same SA on shared SA requirements”, Endsley and Jones 2001, 48) has been adopted to emphasise the overlapping of knowledge in CMTs, TSA (“the degree to which every team member possesses the SA required for his or her responsibilities”, Endsley 1995, 39) has been adopted to reflect the needs for the distribution of knowledge in CMTs (see Table 8).

3.1.5. Distributed cognition

DC, a construct originated from the context of military command and control, explains how cognitive knowledge and processes “in the wild” (e.g., navigating U.S. naval vessels or landing an aircraft) may be dynamically distributed across sociotechnical systems (Hutchins 1995). DC in CMTs has been generally defined as cognitive knowledge and processes that exist across individuals, artefacts, internal/external information, and time (see Table 9).

3.1.6. Interactive team cognition (ITC) or team cognition as interaction

While knowledge-based constructs such as SMM or TMM conceptualise an aggregation of individual knowledge as inputs to team cognition, ITC postulates that team cognition is an activity embodied by interactions (Cooke et al. 2013; Cooke and Gorman 2009). ITC in CMTs has been generally defined as team information processing activities enacted by dynamic interactions among team members (see Table 10).

3.1.7. Transactive memory systems (TMS)

TMS has been conceptualised as a multidimensional construct to explain how people in close relationships (e.g., romantic couples) work together, under both knowledge- and interaction-based assumptions (i.e., group knowledge stock, consensus about knowledge sources, specialisation of expertise, and accuracy of knowledge identification; Austin 2003; i.e., knowledge

specialisation, credibility, and coordination; Lewis 2003). As shown in Table 11, TMS in CMTs has been generally defined as a group’s (referred to as a system) ability to encode, store, retrieve, and communicate information through coordination processes, under both knowledge- and interaction-based assumptions.

3.1.8. Distributed situation awareness (DSA)

DSA (Stanton et al. 2006) expands the meaning of SA, an individual-level construct originated from the context of an aircraft cockpit, to a system-level for the application to the context of military command and control. Unlike SSA/TSA in which a team is a common unit of analysis, DSA often involves an expanded scope such as an entire sociotechnical system. Cognitive knowledge and processes may be distributed across the system’s human and technical agents and represented as a network which tells us if “the right information is activated and passed to the right agent at the right time” (Stanton 2016, 2). As shown in Table 12, DSA in CMTs has been generally defined as taskwork-related knowledge dynamically becoming activated within a system of CMTs to achieve the system-level goals through interactions.

3.1.9. Shared belief

Shared belief is a measure of team functioning grounded in constructs such as SA, SMM, and SSA to estimate the similarity between team members’ beliefs. Shared beliefs in CMTs is defined as the similarity of a team member’s responses to the best-informed member’s beliefs (representing a measure of SSA) and the team average beliefs (representing a measure of SMM), assuming a knowledge-based perspective (see Table 13). Shared belief exemplifies an effort to integrate SSA and SSM based on a common theoretical (knowledge-based) assumption.

3.1.10. Macrocognition

Macrocognition refers to cognition occurring across multiple individuals and teams in complex collaborative environments (Miller and Patterson 2018). Macrocognition in teams emphasises the cognitive process of individuals and teams to adapt to novel situations (Fiore et al. 2010). Macrocognition in CMTs has been generally adopted to describe collective cognition occurring in crisis management multiteam systems where constant attention shift is needed between intra-team and inter-team information processing (see Table 14).

Table 16. A synthesis of the definitions across three dimensions of analysis.

(a) Associated construct	(b) Theoretical assumption(s)			Total	(c) Unit of analysis	
	Knowledge	Interaction	Both		Team	Multiteam
Collective sensemaking	–	13	–	13		✓
Shared/team mental model (SMM/TMM)	11	–	–	11	✓	
Common operating picture (COP)	5	5	–	10		✓
Shared/team situation awareness (SSA/TSA)	–	–	8	8	✓	
Distributed cognition (DC)	–	–	5	5		✓
Interactive team cognition (ITC)	–	4	–	4	✓	
Transactive memory system (TMS)	–	–	3	3	✓	
Distributed situation awareness (DSA)	–	–	3	3		✓
Shared belief	2	–	–	2	✓	
Macro cognition in teams	–	–	2	2		✓
Team metacognition	–	–	1	1		✓
Cognition in a CMT	13	4	11	28	✓	
Cognition in a system of CMTs	5	18	11	34		✓
Total	18	22	22	62		

Note: Three articles were coded twice: (Wolbers and Boersma 2013) for both collective sensemaking and COP; (Uitdewilligen and Waller 2018) for both collective sensemaking and ITC; (Luokkala and Virrantaus 2014) for both COP and TSA.

3.1.11. Team metacognition

Team metacognition (Hinsz 2004) expands metacognition to team- or multiteam-level. Metacognition (Flavell 1979) originated from the context of young children's learning as a construct referring to the cognitive processes used to understand and control one's own cognitive states and processes. While metacognition has been used to describe individual incident commanders' effective decision making, team metacognition has been studied as a critical construct for the effectiveness of CMTs. Team metacognition in CMTs has been defined under both knowledge- and interaction-based assumptions, with an emphasis on achieving team- or system-level goals (see Table 15).

3.2. A synthesis of the definitions

Despite conceptual differences among the definitions, there are several opportunities for their harmonisation and an integrated viewpoint of team cognition in the CMT domain. Our three dimensions of analysis (i.e., associated construct, theoretical assumption(s), and unit of analysis; Table 4) provided a framework to understand the similarities and variabilities in the definitions of cognition in CMTs, and thereby identify potential opportunities for harmonisation. Table 16 summarises our assessment of the definitions across the three dimensions of analysis.

As overviewed earlier, we identified 11 different constructs associated with cognition in CMTs. While five out of the 11 constructs focussed on a team as a unit of analysis conceptualising (intra-team) cognition in a CMT, six emphasised a multiteam as a unit of analysis conceptualising (intra- and inter-team) cognition in a system of CMTs (Table 16).

Those constructs mapped their underlying assumptions into one of three cases, i.e., knowledge-based

(18 out of 62 instances), interaction-based (22 out of 62 instances), or both (22 out of 62 instances). This finding from an analysis of the first and second dimensions indicates that there was no single predominant theoretical assumption across multiple constructs identified in this review. However, we found a contrasting trend when incorporating the third dimension, i.e., the unit of analysis. While a majority of the constructs conceptualising (intra-team) cognition in a CMT are largely driven by knowledge-based assumption (13 knowledge-based vs. four interaction-based), a majority of constructs conceptualising (intra- and inter-team) cognition in a system of CMTs embraces interaction-based assumption (five knowledge-based vs. 18 interaction-based).

In what follows, we argue that the unique characteristics of CMTs make them more aligned with the operationalisation of (intra- and inter-team) cognition in a system of CMTs. We then use the conceptualising trends and aggregate them into an integrative definition of cognition in CMTs.

3.2.1. Defining cognition as interaction within and across the components of a system of CMTs

Our synthesis of definitions showed that constructs conceptualising cognition in a system of CMTs tended to use the interaction-based theory of cognition (Table 16). Also, a majority of those constructs conceptualise both intra-team and inter-team cognition. We argue that the known characteristics and properties of CMTs make these systems more in line with this interaction-based view of cognition.

First, CMTs are heterogeneous, often large, and quickly formed with pre-existing structures designed for the management of a variety of crisis informational needs. For instance, an incident management team, a specific type of CMT that continuously handles

complex information management process with the delegated authority to act on behalf of the affected jurisdiction(s), are purposefully composed of members with heterogeneous experience, knowledge, and cultural backgrounds, based on the national incident management system (NIMS; Federal Emergency Management Agency 2017). Therefore, the cognitive functioning of CMTs necessitates more than sharing knowledge among the members; it requires appropriate interactions among the heterogeneous members of CMTs.

Second, as disaster scenarios change frequently and unpredictably, CMT members interact in a nonlinear, interdependent, and dynamic way, with reliance on technological tools if needed (Jenkins et al. 2010). Technology, indeed, has been realised as a team-mate or a contributor to ITC (Cooke and Gorman 2009; Fiore and Wiltshire 2016). Although the extracted definitions mainly deal with the social aspects of CMTs, the concept of technology-as-team-mate appeared in definitions of DC (Furniss & Blandford 2006; Plant and Stanton 2014, 2016; Rybing et al. 2016; Toupes, Kerne, and Hamilton 2011) and DSA (Curnin et al. 2015; Fleştea et al. 2017; Heard et al. 2014). This indicates a need to view a CMT as a cognitive system embedded in socio-technical systems and understand its cognition as (technologically mediated) interactive patterns within and across the system components, i.e., team members.

Third, CMTs are interdependent; their collective cognitive functioning requires interactions within as well as across CMTs. The naturalistic CMT context has been represented as a multiteam system in many definitions (e.g., Benamrane and Boustras 2015; Bergeron and Cooren 2012; Fleştea et al. 2017; McLennan et al. 2006; McMaster and Baber 2012; van de Walle, Brugghehans, and Comes 2016), appreciating cognition as interactions simultaneously occurring at multiple levels. Macrocognition, for instance, was adopted to define cognition in complex collaborative environments such as CMTs to occur with constant attentional shift across multiple levels (Alison et al. 2015; Handley and Heacox 2010). Such a conceptualising tendency further suggests considering a system of CMTs as a cognitive system-of-systems extending the abovementioned view of a CMT as a cognitive system towards a system-of-systems level (Maier 1998), and incorporate interactions simultaneously occurring among human and technical agents at multiple levels (i.e., system-of-systems, system, and sub-system) into the integrative definition of cognition in CMTs.

To summarise, our synthesis shows that cognition in a system of CMTs can be embodied as interactions

across the system components, i.e., team members and CMTs, especially considering the heterogeneous, dynamic, and interdependent nature of the CMTs with reliance on technological tools if needed.

3.2.2. *Defining cognition as the capability of a system of CMTs to perceive, diagnose, and adapt*

Our findings suggest that there is a tendency to emphasise the system capability to “[collectively] recognize the degree of emerging risk to which a community is exposed and to act on that information” (Comfort 2007, 189) while conceptualising both intra-team and inter-team cognition. Grounded in our previous research (Moon, Peres, and Sasangohar 2017, Moon et al. 2018) and current review of definitions, we argue that cognition in a system of CMTs is the system’s (or the cognitive system-of-system’s) ability to span across three distinct cognitive processes: perceiving, diagnosing, and adapting to crisis information.

First, perceiving is a collective cognitive process of becoming aware of knowledge, which takes place through interactions within and across CMTs for recognising, seeking, and/or collecting information. In reflection of Hurricane Katrina, Comfort (2007, 193) explicitly emphasised perceiving in crisis management as a process of quickly scanning for discrepancies between “what they [i.e., CMT members] view as normal performance and the change in the status of key indicators that alerts them to potential danger”, rather than reviewing the entire set of rules of operation. The importance of proper perception of the status of critical elements for realistic situation assessment is reflected in the definitions of knowledge-based COP and TSA. The definitions of knowledge-based COP depict an input for perceiving, i.e., “a manipulable visualization of what is happening and where resources are that is open to all members of the emergency management team” (Carver and Turoff 2007, 36). On the other hand, the definitions of TSA, a construct conceptualising intra-team cognition, implicitly acknowledge perceiving as an expansion of one of the three levels of an individual SA (i.e., perception, comprehension, and projection; Endsley 1995) to a team level.

Second, diagnosing is a collective cognitive process of characterising perceived knowledge, which takes place through interactions for clarifying, interpreting, examining, and/or evaluating the information. Diagnosing in crisis management was highlighted as a process of “integrating incoming information [...] into a current assessment of vulnerability” (Comfort 2007, 193). The importance of knowledge diagnosis from

heterogeneous perspectives (at least from the unique perspectives of an initiator and a receiver of an interaction) has been reflected in the definitions of collective sensemaking, interaction-based COP, and TMS. Notably, Wolbers and Boersma (2013, 188–189) attempted to integrate the definitions of collective sensemaking and interaction-based COP from the diagnosing (D) perspective, e.g., a process of “combining different cues, roles, scripts, and actions that arise from the actors’ different institutional backgrounds,” “negotiate[ing] their plurality of points of view,” and “give[ing] meanings to information to synchronize their actions”. In line with collective sensemaking’s elucidation of cognition as negotiation, the theorists of interaction-based COP argue that “[a COP] needs to go beyond the concept of a data warehouse, and move towards a situation in which the individual actors share their expertise and exchange ideas, learn from one another and make sense of each other’s position and institutional background” (Tatham, Spens, and Kovács 2017, 84). On the other hand, TMS, a construct conceptualising intra-team cognition, has described that diagnosing process depends on heterogeneous perspective of CMT members stored in a collective long-term memory such as a TMS, analogous to the top-down processing mechanism of an individual’s cognition which depends on the experiences stored in long-term memory (Majchrzak, Jarvenpaa, and Hollingshead 2007; Marques-Quinteiro et al. 2013; van der Haar, Jehn, and Segers 2008).

Third, adapting is a collective cognitive process of adjusting to perceived and/or diagnosed knowledge, which takes place through interactions for establishing, modifying, and/or executing the courses of action in reactive and/or proactive manner. In frequently changing and unpredictable disaster scenarios, CMTs should go beyond the mere sharing of knowledge on the most likely future states and manage their courses of action almost immediately over continued operational periods (FEMA 2017). The importance of adapting has been reflected in the definitions of collective sensemaking, COP, macrocognition, SMM, and ITC. The definitions of collective sensemaking have emphasised the importance of dynamic communication for collaborative storytelling (Benamrane and Boustras 2015; Bergeron and Cooren 2012; Giordano et al. 2017; Landgren 2005; Malakis and Kontogiannis 2014; Mirbabaie and Marx 2020; Takeda, Jones, and Helms 2017; Uitdewilligen and Waller 2018; Waring et al. 2018; Weick 1993; Wolbers, Boersma, and Groenewegen 2018; Wolbers and Boersma 2013; Wu et al. 2013). The definitions of interaction-based COP

have viewed such an open communication opportunity as a basis for continuous and adaptive coordination (Baber et al. 2013; Comfort 2007; Steigenberger 2016; Tatham, Spens, and Kovács 2017; Wolbers and Boersma 2013). COP has been interpreted as “a platform that allows experts to coordinate and negotiate their plurality of points of view” where collective sensemaking can occur (Wolbers and Boersma 2013, 188–189). The definitions of macrocognition have highlighted the way CMTs adapt to novel situations through negotiation between intra-team and inter-team cognition, such as an example of “police officers operate with their ‘intra-agency’ police colleagues along with their ‘interagency’ emergency response colleagues (e.g., fire and ambulance services), who have both cohesive and conflicting goals depending on the incident and required outcome” (Alison et al. 2015, 297–298; cf. Handley and Heacox 2010). The definitions of SMM, a construct conceptualising intra-team cognition, have appreciated adapting as the team’s ability to revise action plans based on the perception of changing situations (Owen et al. 2013). Also, the definitions of ITC have defined cognition in a CMT as “the ability to adaptively reorganise team coordination processes, in response to novel or challenging events” (Gorman et al. 2019, 1, 4).

In summary, cognition in a system of CMTs may be generalised as a collective activity in which heterogeneous perspectives can be continuously negotiated through interactions to support improved perception and diagnosis of relevant events as well as adaptive coordination. Indeed such adaptation, as a core cognitive process in CMTs, has been recognised in multi-team systems literature as self-organising behaviours of complex adaptive systems (Zaccaro, Marks, and DeChurch 2012).

3.2.3. *An integrative definition as a general guide of reference*

Grounded in our synthesis of definitions for cognition in CMTs and three contextual characteristics of CMTs—namely: heterogeneity, dynamic reliance on technology, and inter-team interdependency—we argued that cognition in a system of CMTs might be better realised through interactions within and across CMTs. We also argued that such interaction supports the system’s ability to span across three distinct cognitive processes of CMTs: perceiving, diagnosing, and adapting to crisis information.

Therefore, building on Comfort’s (2007, 189) seminal definition of cognition in crisis management (“the capacity to recognise the degree of emerging risk to

which a community is exposed and to act on that information”), we define cognition in CMTs as *the capability of a system of CMTs to collectively perceive, diagnose, and adapt to the degree of emerging risk to which a community is exposed, which takes place through nonlinear, interdependent, dynamic, and technologically mediated (if needed) interactions within and across the component CMTs.*

4. Conclusion and future research agenda

Functional and efficient CMTs are a necessity for effective disaster response. Given the complex and multi-layer nature of the crisis management domain, an integrative understanding of cognition in CMTs is a necessary condition for future improvements in CMTs’ functioning and resilience. Despite relevant research in this field, uni-disciplinary and isolated characteristics of previous efforts have limited the accumulation of knowledge in this field. To address such a gap, the current paper makes two arguments to contextualise cognition in CMTs in terms of its associated constructs, theoretical assumptions, and unit of analysis for a more integrated understanding. The first argument posits that cognition in a system of CMTs can be realised as interactions at multiple levels of the system. The second argument elucidates that cognition in a system of CMTs can be realised as the system’s capability for collective perception, diagnosis and adaptation. With those arguments as building blocks, an integrative definition of cognition in a system of CMTs was presented.

The proposed definition harmonises various theories and constructs of both team and multiteam cognition. The current review of definitions could serve as the necessary step in the conceptualisation and operationalisation of cognition in CMTs for future research. Indeed, our work suggests large variability in operationalisations. Our work interpreted a CMT as a cognitive system which perceives, diagnoses, and adapts to information, providing the means to operationalise cognition in a system of CMTs as interactions within and across the cognitive systems, advancing the Wickens’ (1992) individual information processing theory and the ITC theory to a system or system-of-systems level.

The proposed definition’s applicability to a layered CMT environment is higher compared to other definitions of team cognition constructs; however, its generalisation to a wide variety of teams (or multiteams) should be considered carefully. With regard to the search, selection, and categorisation of definitions, our

approach focused on a limited range of articles which could be easily coded in terms of construct and theory. More work is needed to verify the distinction between perceiving, diagnosing, and adapting. Therefore, other conceptualisation and the corresponding operationalisations cannot be entirely excluded and could have yielded alternative results.

Although the current review offers an initial contribution to the literature through a synthesis of conceptualisations, research is needed to generate empirical evidence evaluating the operationalisation of our integrative definition and assessing its practicality to inform future policies and practices for a coordinated response within and among CMTs. Although ITC has been modelled and measured through dynamic systems modelling of team verbal behaviours (Cooke and Gorman 2009; Gorman, Cooke, and Amazeen 2010; McNeese et al. 2018), modelling and measuring cognition in real-world CMTs remains relatively unexplored. Work is in progress to investigate whether the new definition can inform a descriptive model of cognition in CMTs and evaluate the efficacy of such a model in assessing how effectively and efficiently a system of CMTs, as a cognitive system-of-systems, perceive, diagnose, and adapt to information. In pursuit of these research questions, we can better design CMTs’ working environments and training practices, thereby improving CMTs’ cognitive ability to respond to complex and unexpected events and to save lives and infrastructures.

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ORCID

Jukrin Moon  <http://orcid.org/0000-0001-5008-9742>
 Farzan Sasangohar  <http://orcid.org/0000-0001-9962-5470>
 Changwon Son  <http://orcid.org/0000-0002-8405-481X>
 S. Camille Peres  <http://orcid.org/0000-0002-3679-9171>

References

- Alison, L., N. Power, C. Heuvel, M. Humann, M. Palasinski, and J. Crego. 2015. "Decision Inertia: Deciding between Least Worst Outcomes in Emergency Responses to Disasters." *Journal of Occupational and Organizational Psychology* 88 (2): 295–321. doi:10.1111/joop.12108.
- Austin, J. R. 2003. "Transactive Memory in Organizational Groups: The Effects of Content, Consensus, Specialization, and Accuracy on Group Performance." *The Journal of Applied Psychology* 88 (5): 866–878. doi:10.1037/0021-9010.88.5.866.
- Baber, C., N. A. Stanton, J. Atkinson, R. McMaster, and R. J. Houghton. 2013. "Using Social Network Analysis and Agent-Based Modelling to Explore Information Flow Using Common Operational Pictures for Maritime Search and Rescue Operations." *Ergonomics* 56 (6): 889–905. doi:10.1080/00140139.2013.788216.
- Benamrane, Y., and G. Boustras. 2015. "Atmospheric Dispersion and Impact Modeling Systems: How Are They Perceived as Support Tools for Nuclear Crises Management?" *Safety Science* 71: 48–55. doi:10.1016/j.ssci.2014.09.002.
- Bergeron, C. D., and F. Cooren. 2012. "The Collective Framing of Crisis Management: A Ventriloquist Analysis of Emergency Operations Centres." *Journal of Contingencies and Crisis Management* 20 (3): 120–137. doi:10.1111/j.1468-5973.2012.00671.x.
- Bharosa, N., J. Lee, and M. Janssen. 2010. "Challenges and Obstacles in Sharing and Coordinating Information during Multi-Agency Disaster Response: Propositions from Field Exercises." *Information Systems Frontiers* 12 (1): 49–65. doi:10.1007/s10796-009-9174-z.
- Bigley, G. A., and K. H. Roberts. 2001. "The Incident Command System: High-Reliability Organizing for Complex and Volatile Task Environments." *Academy of Management Journal* 44 (6): 1281–1299. doi:10.5465/3069401.
- Bunker, D., L. Levine, and C. Woody. 2015. "Repertoires of Collaboration for Common Operating Pictures of Disasters and Extreme Events." *Information Systems Frontiers* 17 (1): 51–65. doi:10.1007/s10796-014-9515-4.
- Cannon-Bowers, J. A., and E. Salas. 2001. "Reflections on Shared Cognition." *Journal of Organizational Behavior* 22 (2): 195–202. doi:10.1002/job.82.
- Cannon-Bowers, J. A., E. Salas, and Converse. 1990. "Cognitive Psychology and Team Training: Training Shared Mental Models and Complex Systems." *Human Factors Society Bulletin* 33 (12), 1–4.
- Carter, E., and S. French. 2006. "Are Current Processes for Nuclear Emergency Management in Europe Adequate?" *Journal of Radiological Protection: Official Journal of the Society for Radiological Protection* 26 (4): 405–414. doi:10.1088/0952-4746/26/4/005.
- Carver, L., and M. Turoff. 2007. "Human-Computer Interaction: The Human and Computer as a Team in Emergency Management Information Systems." *Communications of the ACM* 50 (3): 33–38. doi:10.1145/1226736.1226761.
- Comfort, L. K. 2002. "Rethinking Security: Organizational Fragility in Extreme Events." *Public Administration Review* 62 (s1): 98–107. doi:10.1111/1540-6210.62.s1.18.
- Comfort, L. K. 2007. "Crisis Management in Hindsight: Cognition, Communication, Coordination, and Control." *Public Administration Review* 67 (s1): 189–197. doi:10.1111/j.1540-6210.2007.00827.x.
- Comfort, L. K., and N. Kapucu. 2006. "Inter-Organizational Coordination in Extreme Events: The World Trade Center Attacks, September 11, 2001." *Natural Hazards* 39 (2): 309–327. doi:10.1007/s11069-006-0030-x.
- Cooke, N. J., and J. C. Gorman. 2009. "Interaction-Based Measures of Cognitive Systems." *Journal of Cognitive Engineering and Decision Making* 3 (1): 27–46. doi:10.1518/15534309X433302.
- Cooke, N. J., J. C. Gorman, and J. L. Winner. 2008. "Team Cognition." In *Handbook of Applied Cognition*, 239–268. Hoboken, NJ: John Wiley & Sons, Ltd. doi:10.1002/9780470713181.ch10.
- Cooke, N. J., J. C. Gorman, C. W. Myers, and J. L. Duran. 2013. "Interactive Team Cognition." *Cognitive Science* 37 (2): 255–285. doi:10.1111/cogs.12009.
- Curnin, S., C. Owen, D. Paton, and B. Brooks. 2015. "A Theoretical Framework for Negotiating the Path of Emergency Management Multi-Agency Coordination." *Applied Ergonomics* 47: 300–307. doi:10.1016/j.apergo.2014.10.014.
- DeChurch, L. A., and J. R. Mesmer-Magnus. 2010. "The Cognitive Underpinnings of Effective Teamwork: A Meta-Analysis." *The Journal of Applied Psychology* 95 (1): 32–53. doi:10.1037/a0017328.
- DeChurch, L. A., and S. J. Zaccaro. 2010. "Perspective: Teams Won't Solve This Problem." *Human Factors* 52 (2): 329–334. doi:10.1177/0018720810374736.
- Ehnis, C., and D. Bunker. 2020. "Repertoires of Collaboration: Incorporation of Social Media Help Requests into the Common Operating Picture." *Behaviour & Information Technology* 39 (3): 343–317. doi:10.1080/0144929X.2019.1621934.
- Endsley, M. R. 1995. "Measurement of Situation Awareness in Dynamic Systems." *Human Factors: The Journal of the Human Factors and Ergonomics Society* 37 (1): 65–84. doi:10.1518/001872095779049499.
- Endsley, M. R., and D. G. Jones. 2001. "Disruptions, Interruptions and Information Attack: Impact on Situation Awareness and Decision Making." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 45 (2): 63–67. doi:10.1177/154193120104500214.
- Federal Emergency Management Agency. 2017. *National incident management system (3rd ed.)*. FEMA. 133. Retrieved from: <https://www.hsdl.org/?view&did=804929>
- Fiore, S. M., and E. Salas. 2004. "Why Need Team Cognition." In *Team Cognition: Understanding the Factors that Drive Process And Performance*, edited by E. Salas and S. M. Fiore, 235–248. Washington, DC: American Psychological Association.
- Fiore, S. M., and T. J. Wiltshire. 2016. "Technology as Teammate: Examining the Role of External Cognition in Support of Team Cognitive Processes." *Frontiers in Psychology* 7: 1531. doi:10.3389/fpsyg.2016.01531.

- Fiore, S. M., K. A. Smith-Jentsch, E. Salas, N. Warner, and M. Letsky. 2010. "Towards an Understanding of Macrocognition in Teams: Developing and Defining Complex Collaborative Processes and Products." *Theoretical Issues in Ergonomics Science* 11 (4): 250–271. doi:10.1080/14639221003729128.
- Flavell, J. H. 1979. "Metacognition and Cognitive Monitoring: A New Area of Cognitive-Developmental Inquiry." *American Psychologist* 34 (10): 906–911. doi:10.1037/0003-066X.34.10.906.
- Fleștea, A. M., O. C. Fodor, P. L. Curșeu, and M. Miclea. 2017. "We didn't know anything, it was a mess! Emergent structures and the effectiveness of a rescue operation multi-team system." *Ergonomics* 60 (1): 44–58. doi:10.1080/00140139.2016.1162852.
- Furniss, D., and A. Blandford. 2006. "Understanding Emergency Medical Dispatch in Terms of Distributed Cognition: A Case Study." *Ergonomics* 49 (12–13): 1174–1203. doi:10.1080/00140130600612663.
- Giordano, R., A. Pagano, I. Pluchinotta, R. O. del Amo, S. M. Hernandez, and E. S. Lafuente. 2017. "Modelling the Complexity of the Network of Interactions in Flood Emergency Management: The Lorca Flash Flood Case." *Environmental Modelling & Software* 95: 180–195. doi:10.1016/j.envsoft.2017.06.026.
- Gorman, J. C., N. J. Cooke, and P. G. Amazeen. 2010. "Training Adaptive Teams." *Human Factors* 52 (2): 295–307. doi:10.1177/0018720810371689.
- Gorman, J. C., N. J. Cooke, and J. L. Winner. 2006. "Measuring Team Situation Awareness in Decentralized Command and Control Environments." *Ergonomics* 49 (12–13): 1312–1325. doi:10.1080/00140130600612788.
- Gorman, J. C., D. A. Grimm, R. H. Stevens, T. Galloway, A. M. Willemssen-Dunlap, and D. J. Halpin. 2019. "Measuring Real-Time Team Cognition during Team Training." *Human Factors*: 001872081985279. doi:10.1177/0018720819852791.
- Grunwald, J. A., and C. Bearman. 2017. "Identifying and Resolving Coordinated Decision Making Breakdowns in Emergency Management." *International Journal of Emergency Management* 13 (1): 68–86. doi:10.1504/IJEM.2017.081198.
- Handley, H. A. H., and N. J. Heacox. 2010. "Collaborative Multinational Mission Planning System with Support for Macrocognitive Processes." *Theoretical Issues in Ergonomics Science* 11 (4): 375–386. doi:10.1080/14639221003729219.
- Heard, J., S. Thakur, J. Losego, and K. Galluppi. 2014. "Big Board: Teleconferencing over Maps for Shared Situational Awareness." *Computer Supported Cooperative Work (CSCW)* 23 (1): 51–74. doi:10.1007/s10606-013-9191-9.
- Hinsz, V. B. 2004. "Metacognition and Mental Models in Groups: An Illustration with Metamemory of Group Recognition Memory." In *Team Cognition: Understanding the Factors That Drive Process and Performance*, 33–58. Washington, DC: American Psychological Association.
- Hutchins, E. 1995. *Cognition in the Wild*. Cambridge, MA: The MIT Press.
- Intergovernmental Panel on Climate Change. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom: Cambridge University Press.
- Jenkins, D. P., P. M. Salmon, N. A. Stanton, and G. H. Walker. 2010. "A New Approach for Designing Cognitive Artefacts to Support Disaster Management." *Ergonomics* 53 (5): 617–635. doi:10.1080/00140131003672007.
- Jenuwine, E. S., and J. A. Floyd. 2004. "Comparison of Medical Subject Headings and Text-Word Searches in MEDLINE to Retrieve Studies on Sleep in Healthy Individuals." *Journal of the Medical Library Association : JMLA* 92 (3): 349–354. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC442177/>.
- Kaber, D. B., and M. R. Endsley. 1998. "Team Situation Awareness for Process Control Safety and Performance." *Process Safety Progress* 17 (1): 43–48. doi:10.1002/prs.680170110.
- Landgren, J. 2005. "Supporting Fire Crew Sensemaking Enroute to Incidents." *International Journal of Emergency Management* 2 (3): 176. doi:10.1504/IJEM.2005.007358.
- Langan-Fox, J., J. Anglim, and J. R. Wilson. 2004. "Mental Models, Team Mental Models, and Performance: Process, Development, and Future Directions." *Human Factors and Ergonomics in Manufacturing* 14 (4): 331–352. doi:10.1002/hfm.20004.
- Lewis, K. 2003. "Measuring Transactive Memory Systems in the Field: Scale Development and Validation." *The Journal of Applied Psychology* 88 (4): 587–604. doi:10.1037/0021-9010.88.4.587.
- Liu, J., Y. Qin, Q. Yang, C. Yu, and Y. Shi. 2015. "A Tabletop-Centric Smart Space for Emergency Response." *IEEE Pervasive Computing* 14 (2): 32–40. doi:10.1109/MPRV.2015.24.
- Luukkala, P., and K. Virrantaus. 2014. "Developing Information Systems to Support Situational Awareness and Interaction in Time-Pressuring Crisis Situations." *Safety Science* 63: 191–203. doi:10.1016/j.ssci.2013.11.014.
- Maier, M. W. 1998. "Architecting Principles for Systems-of-Systems." *Systems Engineering* 1 (4): 267–284. doi:10.1002/(SICI)1520-6858(1998)1:4<267::AID-SYS3>3.0.CO;2-D.
- Majchrzak, A., S. L. Jarvenpaa, and A. B. Hollingshead. 2007. "Coordinating Expertise among Emergent Groups Responding to Disasters." *Organization Science* 18 (1): 147–161. doi:10.1287/orsc.1060.0228.
- Malakis, S., and T. Kontogiannis. 2014. "Exploring Team Sensemaking in Air Traffic Control (ATC): Insights from a Field Study in Low Visibility Operations." *Cognition, Technology & Work* 16 (2): 211–227. doi:10.1007/s10111-013-0258-7.
- Marques-Quinteiro, P., L. Curral, A. M. Passos, and K. Lewis. 2013. "And Now What Do we Do? the Role of Transactive Memory Systems and Task Coordination in Action Teams." *Group Dynamics: Theory, Research, and Practice* 17 (3): 194–206. doi:10.1037/a0033304.
- McHugh, M. L. 2012. "Interrater Reliability: The Kappa Statistic." *Biochemia Medica* 22 (3): 276–282. <https://hrcak.srce.hr/89395>. doi:10.11613/BM.2012.031.
- McLennan, J., A. M. Holgate, M. M. Omodei, and A. J. Wearing. 2006. "Decision Making Effectiveness in Wildfire Incident Management Teams." *Journal of Contingencies and Crisis Management* 14 (1): 27–37. doi:10.1111/j.1468-5973.2006.00478.x.
- McMaster, R., and C. Baber. 2012. "Multi-Agency Operations: Cooperation during Flooding." *Applied Ergonomics* 43 (1): 38–47. doi:10.1016/j.apergo.2011.03.006.
- McNeese, N. J., M. Demir, N. J. Cooke, and C. Myers. 2018. "Teaming with a Synthetic Teammate: Insights into

- Human-Autonomy Teaming." *Human Factors* 60 (2): 262–273. doi:[10.1177/0018720817743223](https://doi.org/10.1177/0018720817743223).
- Militello, L. G., E. S. Patterson, L. Bowman, and R. Wears. 2007. "Information Flow during Crisis Management: Challenges to Coordination in the Emergency Operations Center." *Cognition, Technology & Work* 9 (1): 25–31. doi:[10.1007/s10111-006-0059-3](https://doi.org/10.1007/s10111-006-0059-3).
- Miller, J. E., and E. S. Patterson. 2018. *Macro cognition metrics and scenarios: Design and evaluation for real-world teams*. Boca Raton, FL: CRC Press.
- Mirbabaie, M., and J. Marx. 2020. "Breaking' News: Uncovering Sense-Breaking Patterns in Social Media Crisis Communication during the 2017 Manchester Bombing." *Behaviour & Information Technology* 39 (3): 252–215. doi:[10.1080/0144929X.2019.1611924](https://doi.org/10.1080/0144929X.2019.1611924).
- Mohammed, S., L. Ferzandi, and K. Hamilton. 2010. "Metaphor No More: A 15-Year Review of the Team Mental Model Construct." *Journal of Management* 36 (4): 876–910. doi:[10.1177/0149206309356804](https://doi.org/10.1177/0149206309356804).
- Mohammed, S., K. Hamilton, R. Tesler, V. Mancuso, and M. McNeese. 2015. "Time for Temporal Team Mental Models: Expanding beyond "What" and "How" to Incorporate "When." *European Journal of Work and Organizational Psychology* 24 (5): 693–709. doi:[10.1080/1359432X.2015.1024664](https://doi.org/10.1080/1359432X.2015.1024664).
- Moher, D., A. Liberati, J. Tetzlaff, D. G. Altman, and T. P. Group, PRISMA Group. 2009. "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement." *PLoS Medicine* 6 (7): e1000097. doi:[10.1371/journal.pmed.1000097](https://doi.org/10.1371/journal.pmed.1000097).
- Moon, J., S. C. Peres, and F. Sasangohar. 2017. "Defining Team Cognition in Emergency Response: A Scoping Literature Review." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 61 (1): 894–895. doi:[10.1177/1541931213601702](https://doi.org/10.1177/1541931213601702).
- Moon, J., F. Sasangohar, S. C. Peres, T. J. Neville, and C. Son. 2018. "Modeling Team Cognition in Emergency Response via Naturalistic Observation of Team Interactions." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 62 (1): 1801–1802. doi:[10.1177/1541931218621408](https://doi.org/10.1177/1541931218621408).
- National Oceanic and Atmospheric Administration. 2019. *U.S. Billion-dollar Weather and Climate Disasters*. National Centers for Environment Information. Retrieved from <https://www.ncdc.noaa.gov/billions/>
- Norris, W., A. Volda, L. Palen, and S. Volda. 2019. *Is the Time Right Now?: Reconciling Sociotemporal Disorder in Distributed Team Work*. New York, NY: Association for Computing Machinery.
- Ouzzani, M., H. Hammady, Z. Fedorowicz, and A. Elmagarmid. 2016. "Rayyan-a web and mobile app for systematic reviews." *Systematic Reviews* 5 (1): 210. doi:[10.1186/s13643-016-0384-4](https://doi.org/10.1186/s13643-016-0384-4).
- Owen, C., C. Bearman, B. Brooks, J. Chapman, D. Paton, and L. Hossain. 2013. "Developing a Research Framework for Complex Multi-Team Coordination in Emergency Management." *International Journal of Emergency Management* 9 (1): 1. doi:[10.1504/IJEM.2013.054098](https://doi.org/10.1504/IJEM.2013.054098).
- Pfaff, M. S. 2012. "Negative Affect Reduces Team Awareness: The Effects of Mood and Stress on Computer-Mediated Team Communication." *Human Factors* 54 (4): 560–571. doi:[10.1177/0018720811432307](https://doi.org/10.1177/0018720811432307).
- Plant, K. L., and N. A. Stanton. 2014. "All for One and One for All: Representing Teams as a Collection of Individuals and an Individual Collective Using a Network Perceptual Cycle Approach." *International Journal of Industrial Ergonomics* 44 (5): 777–792. doi:[10.1016/j.ergon.2014.05.005](https://doi.org/10.1016/j.ergon.2014.05.005).
- Plant, K. L., and N. A. Stanton. 2016. "Distributed Cognition in Search and Rescue: Loosely Coupled Tasks and Tightly Coupled Roles." *Ergonomics* 59 (10): 1353–1376. doi:[10.1080/00140139.2016.1143531](https://doi.org/10.1080/00140139.2016.1143531).
- Rybing, J., H. Nilsson, C.-O. Jonson, and M. Bang. 2016. "Studying Distributed Cognition of Simulation-Based Team Training with DiCoT." *Ergonomics* 59 (3): 423–434. doi:[10.1080/00140139.2015.1074290](https://doi.org/10.1080/00140139.2015.1074290).
- Saetrevik, B. 2015. "Psychophysiology, Task Complexity, and Team Factors Determine Emergency Response Teams' Shared Beliefs." *Safety Science* 78: 117–123. doi:[10.1016/j.ssci.2015.04.017](https://doi.org/10.1016/j.ssci.2015.04.017).
- Saetrevik, B., and J. Eid. 2014. "The "Similarity Index" as an Indicator of Shared Mental Models and Situation Awareness in Field Studies." *Journal of Cognitive Engineering and Decision Making* 8 (2): 119–136. doi:[10.1177/1555343413514585](https://doi.org/10.1177/1555343413514585).
- Salas, E., N. J. Cooke, and M. A. Rosen. 2008. "On Teams, Teamwork, and Team Performance: Discoveries and Developments." *Human Factors* 50 (3): 540–547. doi:[10.1518/001872008X288457](https://doi.org/10.1518/001872008X288457).
- Saner, L. D., C. A. Bolstad, C. Gonzalez, and H. M. Cuevas. 2009. "Measuring and Predicting Shared Situation Awareness in Teams." *Journal of Cognitive Engineering and Decision Making* 3 (3): 280–308. doi:[10.1518/155534309X474497](https://doi.org/10.1518/155534309X474497).
- Schraagen, J. M., and J. van de Ven. 2011. "Human Factors Aspects of ICT for Crisis Management." *Cognition, Technology & Work* 13 (3): 175–187. doi:[10.1007/s10111-011-0175-6](https://doi.org/10.1007/s10111-011-0175-6).
- Schraagen, J. M., M. H. Veld, In 't, ' , and L. D. Koning. 2010. "Information Sharing during Crisis Management in Hierarchical vs." *Journal of Contingencies and Crisis Management* 18 (2): 117–127. doi:[10.1111/j.1468-5973.2010.00604.x](https://doi.org/10.1111/j.1468-5973.2010.00604.x).
- Seppänen, H., and K. Virrantaus. 2015. "Shared Situational Awareness and Information Quality in Disaster Management." *Safety Science* 77: 112–122. doi:[10.1016/j.ssci.2015.03.018](https://doi.org/10.1016/j.ssci.2015.03.018).
- Seppänen, H., J. Mäkelä, P. Luukkala, and K. Virrantaus. 2013. "Developing Shared Situational Awareness for Emergency Management." *Safety Science* 55: 1–9. doi:[10.1016/j.ssci.2012.12.009](https://doi.org/10.1016/j.ssci.2012.12.009).
- Shuffler, M. L., M. Jiménez-Rodríguez, and W. S. Kramer. 2015. "The Science of Multiteam Systems: A Review and Future Research Agenda." *Small Group Research* 46 (6): 659–699. doi:[10.1177/1046496415603455](https://doi.org/10.1177/1046496415603455).
- Smith, W., and J. Dowell. 2000. "A Case Study of co-Ordinative Decision-Making in Disaster Management." *Ergonomics* 43 (8): 1153–1166. doi:[10.1080/00140130050084923](https://doi.org/10.1080/00140130050084923).
- Son, J., Z. Aziz, and F. Peña-Mora. 2008. "Supporting Disaster Response and Recovery through Improved Situation Awareness." *Structural Survey* 26 (5): 411–425. doi:[10.1108/02630800810922757](https://doi.org/10.1108/02630800810922757).

- Stachowski, A. A., S. A. Kaplan, and M. J. Waller. 2009. "The Benefits of Flexible Team Interaction during Crises." *The Journal of Applied Psychology* 94 (6): 1536–1543. doi:10.1037/a0016903.
- Stanton, N. A., R. Stewart, D. Harris, R. J. Houghton, C. Baber, R. McMaster, P. Salmon, G. Hoyle, G. Walker, M. S. Young, M. Linsell, R. Dymott, and D. Green. 2006. "Distributed Situation Awareness in Dynamic Systems: Theoretical Development and Application of an Ergonomics Methodology." *Ergonomics* 49 (12–13): 1288–1311. doi:10.1080/00140130600612762.
- Stanton, Neville A. 2016. "Distributed Situation Awareness." *Theoretical Issues in Ergonomics Science* 17 (1): 1–7. doi:10.1080/1463922X.2015.1106615.
- Steigenberger, N. 2016. "Organizing for the Big One: A Review of Case Studies and a Research Agenda for Multi-Agency Disaster Response." *Journal of Contingencies and Crisis Management* 24 (2): 60–72. doi:10.1111/1468-5973.12106.
- Steinke, J., B. Bolunmez, L. Fletcher, V. Wang, A. J. Tomassetti, K. M. Repchick, S. J. Zaccaro, R. S. Dalal, and L. E. Tetrick. 2015. "Improving Cybersecurity Incident Response Team Effectiveness Using Teams-Based Research." *IEEE Security & Privacy* 13 (4): 20–29. doi:10.1109/MSP.2015.71.
- Takeda, M., R. Jones, and M. M. Helms. 2017. "Promoting Sense-Making in Volatile Environments: Developing Resilience in Disaster Management." *Journal of Human Behavior in the Social Environment* 27 (8): 791–805. doi:10.1080/10911359.2017.1338173.
- Tatham, P., K. Spens, and G. Kovács. 2017. "The Humanitarian Common Logistic Operating Picture: A Solution to the Inter-Agency Coordination Challenge." *Disasters* 41 (1): 77–100. doi:10.1111/disa.12193.
- Toups, Z. O., A. Kerne, and W. A. Hamilton. 2011. "The Team Coordination Game: Zero-Fidelity Simulation Abstracted from Fire Emergency Response Practice." *ACM Transactions on Computer-Human Interaction* 18 (4): 1–37. doi:10.1145/2063231.2063237.
- Uitdewilligen, S., and M. J. Waller. 2018. "Information Sharing and Decision-Making in Multidisciplinary Crisis Management Teams." *Journal of Organizational Behavior* 39 (6): 731–748. doi:10.1002/job.2301.
- Uitdewilligen, S., R. Rico, and M. J. Waller. 2018. "Fluid and Stable: Dynamics of Team Action Patterns and Adaptive Outcomes." *Journal of Organizational Behavior* 39 (9): 1113–1128. doi:10.1002/job.2267.
- United Nations Office for Disaster Risk Reduction. 2019. "Global Assessment Report on Disaster Risk Reduction." Retrieved from <https://reliefweb.int/report/world/global-assessment-report-disaster-risk-reduction-2019>
- Valaker, Sigmund, Thorvald Haerem, and Bjørn Tallak Bakken. 2018. "Connecting the Dots in Counterterrorism: The Consequences of Communication Setting for Shared Situation Awareness and Team Performance." *Journal of Contingencies and Crisis Management* 26 (4): 425–439. doi:10.1111/1468-5973.12217.
- van de Walle, B., B. Brugghe, and T. Comes. 2016. "Improving Situation Awareness in Crisis Response Teams: An Experimental Analysis of Enriched Information and Centralized Coordination." *International Journal of Human-Computer Studies* 95: 66–79. doi:10.1016/j.ijhcs.2016.05.001.
- van der Haar, S., K. A. Jehn, and M. Segers. 2008. "Towards a Model for Team Learning in Multidisciplinary Crisis Management Teams." *International Journal of Emergency Management* 5 (3/4): 195. doi:10.1504/IJEM.2008.025091.
- van Santen, W., C. Jonker, and N. Wijngaards. 2009. "Crisis Decision Making through a Shared Integrative Negotiation Mental Model." *International Journal of Emergency Management* 6 (3/4): 342–355. doi:10.1504/IJEM.2009.031570.
- Waller, M. J., N. Gupta, and R. C. Giambatista. 2004. "Effects of Adaptive Behaviors and Shared Mental Models on Control Crew Performance." *Management Science* 50 (11): 1534–1544. doi:10.1287/mnsc.1040.0210.
- Waring, S., L. Alison, G. Carter, C. Barrett-Pink, M. Humann, L. Swan, and T. Zilinsky. 2018. "Information Sharing in Interteam Responses to Disaster." *Journal of Occupational and Organizational Psychology* 91 (3): 591–619. doi:10.1111/joop.12217.
- Wegner, D. M. 1987. "Transactive Memory: A Contemporary Analysis of the Group Mind." In *Theories of Group Behavior*, edited by B. Mullen and G. R. Goethals, 185–208. New York: Springer. doi:10.1007/978-1-4612-4634-3_9.
- Weick, K. E. 1993. "The Collapse of Sensemaking in Organizations: The Mann Gulch Disaster." *Administrative Science Quarterly* 38 (4): 628–652. doi:10.2307/2393339.
- Wickens, C. D. 1992. *Engineering Psychology and Human Performance*, 2nd ed. New York, NY: HarperCollins Publishers.
- Wildman, J. L., E. Salas, and C. P. R. Scott. 2014. "Measuring Cognition in Teams: A Cross-Domain Review." *Human Factors* 56 (5): 911–941. doi:10.1177/0018720813515907.
- Wolbers, J., and K. Boersma. 2013. "The Common Operational Picture as Collective Sensemaking." *Journal of Contingencies and Crisis Management* 21 (4): 186–199. doi:10.1111/1468-5973.12027.
- Wolbers, J., K. Boersma, and P. Groenewegen. 2018. "Introducing a Fragmentation Perspective on Coordination in Crisis Management." *Organization Studies* 39 (11): 1521–1546. doi:10.1177/0170840617717095.
- Wu, A., G. Convertino, C. Ganoe, J. M. Carroll, and X. Zhang. 2013. "Supporting Collaborative Sense-Making in Emergency Management through Geo-Visualization." *International Journal of Human-Computer Studies* 71 (1): 4–23. doi:10.1016/j.ijhcs.2012.07.007.
- Zaccaro, S. J., M. A. Marks, and L. DeChurch. 2012. *Multiteam Systems: An Organization Form for Dynamic and Complex Environments*. Abingdon, United Kingdom: Routledge.