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A protocol for analysing the role of shared situational awareness and decision-making in cooperative disaster simulations

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ABSTRACT

Acute environmental emergencies and disasters call for multi-organisational collaboration where each individual response agency has their own responsibilities and specific roles in an emergency operation. However, different operational systems, cultures and norms between the response agencies can hamper such collaboration and the formation of shared situational awareness (SA). SA has an impact on how an individual response agency understands the situation and therefore forms the basis for decision-making in emergency and disaster management. The premise of this paper is that formation of shared SA is a key to improving preparedness to deal with disasters. The effective formation can be facilitated by creating shared understanding of how disaster management should be implemented. We developed a protocol for analysing the creation of shared SA and its significance for successful operational decision-making during multi-agent disaster simulations. As a starting point, based on a literature review, we built a systemic framework to represent the process of acute operational decision-making, describing particularly the role of the shared SA creation as part of the process. Based on the framework, we then developed a protocol for monitoring the formation and analysing the magnitude of shared SA, how it is linked to the decision making process and the execution of the actions during the exercises. We suggest the protocol can be applied in various emergency and disaster preparedness contexts to support the development and harmonisation of multi-agent and multi-organisational training and future crisis response practises.

1. Introduction

Both the diversity and frequency of major environmental disasters such as the British Petroleum's Deepwater Horizon oil rig explosion [1], Hurricane Katrina [2], the floods in Germany [3] and the bushfires in Australia [4] are growing globally. An individual response agency rarely has the resources or the capacity to overcome such disaster response measures alone [5–8]. Instead, limiting the harm and minimising the damage calls for effective collaborative response activities across organisational, sectoral and, in most cases, national borders [9,10]. However, the collaboration may be hampered by different operational systems, cultures and norms between the agencies [6,11]. Training for multi-agent collaboration can help create shared understanding of how disaster management should be implemented and thereby improve preparedness to deal with it [12,13].

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Situational awareness (SA) provides the basis for decision-making and response measures (i.e. actions) in emergency and disaster management [14]. The formation of SA is a cognitive process for building and maintaining awareness of a situation [15]. An individual agent's or response agency's understanding of a disaster is shaped by SA [16]. SA, on an individual level, denotes how an individual agent acquires it [17]. The common individual SA model defines SA as a product comprising the following three levels: 1) perceiving information about the incident and the prevailing circumstances, 2) interpreting and comprehending the current state and gathered information and then 3) using these to predict future states [17–19]. The team SA is commonly defined as the shared understanding of circumstances between agents on a team at a specific time [14,20]. It is a combination of individual SA agents, the shared SA among agents in a team and the overall SA of the whole team [21]. A systems perspective on SA considers that SA is not just distributed across a team, but it accounts interactions for across the entire system – even the technical artefacts they use [22]. The distributed situation awareness (DSA) model has shifted the focus from the SA of individual agents towards a comprehensive system that includes the transactions in human-to-human, human-to-technology and/or technology-to-technology awareness [22,23]. The inspiration of the DSA model comes largely from the distributed cognition approach where cognition is not recognised as an individual process but rather as a systemic attempt including human agents and artefacts and their relationships in a specific task or practise [24,25]. Thus, DSA illustrates how systems can have awareness [26].

Earlier studies show that collaboration practises (between organisations) [5,27,28], cooperation roles of the actors [29] and their cultural and educational backgrounds [30,31] and cognitive skills [32,33] can have a significant impact on the formation of SA and the following decision-making during emergencies and disasters. Therefore, one of the key aspects in successful cooperative disaster management is to ensure that SA of the individual agents is at a high level and the agencies can form shared SA and understanding of the operation objectives of the operation [8,34]. However, complete sharing of SA among response agencies is not required [35,36]. For instance, the emergency manager or main responsible authority is the central managing party coordinating and leading the response operation [37]. Thus, the party should have all the available information and the best possible SA [29]. As each agent has their responsibilities and specific roles, SA should cover aspects that are relevant for their roles [38].

Repeatable joint trainings between different parties, organisations and countries are useful for harmonisation of the joint response activities and to increase awareness about each other's operational cultures and protocols in an emergency operation [11,29,39]. Several approaches developed for emergency and disaster management training have focused specifically on improving SA, for instance, by describing how different actors understand the situation [16], how actors coordinate and communicate with each other [29,40,41], what the impact of enriched and centralised information is [14] or how to improve the degree of accurate shared SA between actors [42]. However, without constructive feedback and analysis of the performance, lessons learned do not directly translate into good practice in future training or real situations [43–45]. Thus, we provide a science-driven approach to the evidence-based development of trainings, to be used by instructors and analysts of the simulation and preparedness exercises [46,47]. We developed a protocol for analysing the role of shared SA as part of operational decision-making during multi-organisational disaster simulations and the challenges that should be taken into consideration in disaster management. Analysing the sources of resilience and weaknesses in the emergency response system during the training can help to identify further training needs and to plan and improve future exercises [48].

The developed protocol is designed for analytical work to guide and support the development of efficient, spot-on preparedness exercises. It helps the end user to focus on the most relevant aspects to identify what is required in each operation or task (simulated by an exercise) for efficiently creating individual and shared SA that enables successful decisions during the cooperative response operation. To reach this aim, analysing earlier literature, we first built a novel systemic framework to represent the process of operational decision making in the acute disaster management, describing particularly the role of shared SA creation as part of the process. Built on the framework, we then developed the protocol to identify what should be observed to analyse the formation of shared SA and to understand its role in the decision making during the simulations. The framework and protocol are of a general nature, developed having any acute disaster response exercises in mind. However, as discussed in the end of the paper, their applicability in the context of the strategic social-environmental crisis context is worth consideration.

The paper is structured as follows: Section 2 introduces the iterative process of conducting a literature review, creating the systemic framework and further on the protocol. **Section 3.1 presents the SA in the decision-making framework and** Section **3.2 shows the suggested protocol.** In Section 4 we discuss the findings, how they relate to the existing research and how they can help in planning more effective preparedness exercises.

2. Methods and materials

The monitoring protocol was developed through an iterative research process based on in-depth analysis of earlier studies (Fig. 1). First, we conducted a targeted, semi-systematic literature review (see e.g. Refs. [49–51]) to (1) better understand the development of SA and shared SA and the following decision making in operational disaster management, and (2) to see how these have been studied and the related skills developed in different types of learning environments. Unlike the systematic review approach, which usually aims at an all-encompassing quantitative synthesis of a research topic, the semi-systematic or narrative review approach seeks to gain an overview of the research topic and an understanding of the state of the knowledge [50]. It can be used to explore ideas over multiple disciplines, to identify themes and concepts, such as those relevant to the development of shared SA, and to develop theoretical models [49,50,52], as we have done in this study.

We used the Google Scholar web search engine and selected search terms for the initial literature searches. The search terms related to four broader themes: i) disaster and emergency management (e.g. 'crisis management', 'emergency management', 'disaster management'), ii) SA (e.g. 'situational awareness', 'situation awareness', 'operational picture', 'situation picture'), iii) operational

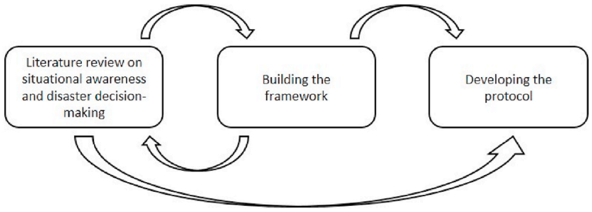

Fig. 1. The iterative research process.

decision making and collaboration (e.g. 'real-time decision-making', 'operational decision-making', 'cooperation', 'cross-border', 'multi-organisational'), and iv) disaster and emergency training (e.g. 'simulation training', 'simulator training', 'preparedness exercise', 'debriefing', 'briefing'). Articles were included or excluded based on their relevance for our study. As not following any systematic literature review protocol, we did not keep track of the numbers of the screened articles, nor the exact search strings. On the contrary, to identify and consider the different dimensions and rich terminology related to the topic as broadly as possible, the so-called snowball method was used throughout the process, to identify additional articles from the reference lists of the reviewed ones [51,53]. We also sought articles that evaluated the learning experiences from simulators, practical emergency and disaster management training and real emergency and disaster management cases. We excluded articles that were more focused on the technical improvement of the simulators, as it was out of our scope.

Second, we synthesised the collected information to a novel systemic framework, which captures the key elements of an operational decision-making process as part of operational disaster management, from initial stimulus to action, particularly focusing on the creation and functions of individual and shared SA. Developing the framework and building links between the elements gave rise to new search terms and topics of interest, including for example, impacts of organisational standards and norms on disaster management, and the relationship between operational and cultural aspects and disaster preparedness.

Third, based on the developed framework and information gained through the earlier studies, we constructed the observation protocol, comprising questions and aspects to be considered when aiming to analyse and improve multi-organisational simulation exercises of disaster management in terms of the formation of SA and effective decision making. Each author first identified these questions and aspects individually, suggesting items or patterns that could be observed for gathering information on the different elements of the framework. The individual ideas were then subjected to several rounds of joint deliberations to formulate the proposed set of analytical questions to be answered and observations to be made, i.e. the protocol.

3. Results

3.1. Framework for decision-making process in disasters

In an emergency response situation, operational leaders are forced to make fast decisions under considerable uncertainties, which make the quality of information constraints tightly connected with the prevailing time constraints [54]. Therefore, the decision-making takes place in an uncertain and dynamically changing environment [55]. The basic elements and processes of the framework for decision-making in disasters are illustrated in Fig. 2. Table 1 explains the key elements of the framework.

As the starting point of building the framework, we used two earlier concepts: the OODA (observe, orient, decide, act) -loop [56,57] and the effects-based action-reaction cycle [58,59], both originally applied in military strategy and warfare contexts. The core idea of both the concepts is the recurring cycle of interrelated elements or the feedback loop to structure decision-making in high-stakes situations. Smith [58,59] included in the effects-based action-reaction cycle a *social domain* that impacts the processes in the *cognitive domain*, as we should not only know how people in general might act but, more importantly, how the reactions of one individual and group differ from others. These concepts were combined, modified and new elements added, as explained in the following sections, to represent how the elements and processes of decision-making in the disaster management context are seen to occur in a multi-domain space. Individual behaviour and collective work organisation in dynamic decision-making situations under time-limited and high-risk conditions has been considered also in other relevant contexts, e.g. in terms of cognitive cooperation [60], common frame of reference [61], team cognition [62], the cognitive load of an individual operator [63], cooperation and situation awareness within and between hierarchical units [64], and cultural influences on decision-making [65].

The framework (Fig. 2) illustrates how the operational decision-making process is initiated by a **stimulus** (A) in the *physical domain* [59]. Reaction to this stimulus begins with the creation of situational picture through the collection of **data (situational picture)** (B) [56,57] in the *information domain*, which entails that response agencies apply tools and practises to acquire data (**data acquisition** [C]) [17]. As raw data may not directly improve the situational picture of the agents, a platform on which the data are integrated, processed and shared is often required (**information systems** [D]) [16,66]. **Communication** (E) between individuals and agencies plays an important role on multiple levels [29,31]. Raw data and the information generated from them should be distributable among the agents who benefit from them. Transparency about the needs and capabilities of and the technologies used (**data acquisition** [C] and **information systems** [D]) by different units are needed for efficient and focused information sharing [67]. **Communication** (E) belongs both under the information domain and the cognitive domain, denoting that it is both about knowledge sharing and interactive cognitive processes [16,29]. **Situational awareness** (F) is seen as the impression and interpretation of what is going on, and it is built on two main elements: **prior knowledge and mental models** (G) and expectations based on those, combined

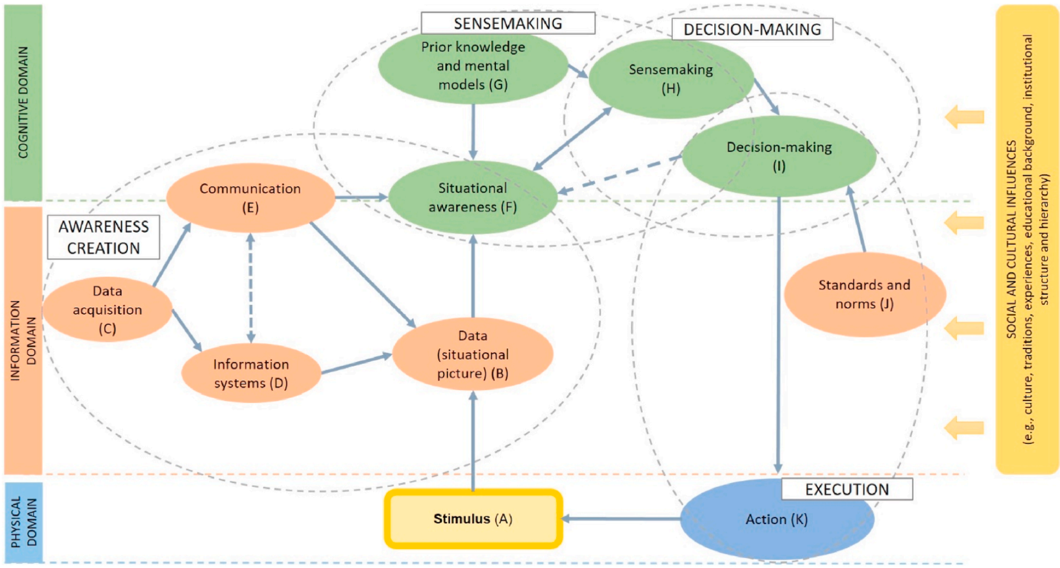

Fig. 2. Framework for the operational decision-making process and the four main phases (awareness creation, sensemaking, decision making, execution) during disaster management. Blue node = element in the physical domain; orange nodes = elements in the information domain; green nodes = elements in the cognitive domain. The identifier letters in each node are referred in other parts of the text.

Table 1
Description of the key elements of the framework in Fig. 2.

Element	Identifier	Description
Stimulus	A	Observed event that either initiates or continues the process.
Data (situational picture)	B	The information of the situation, based on the acquired data (facts, figures and images of the situation, incident, weather, available resources, personnel etc.), i.e. the situational picture.
Data acquisition	C	Tools and practises to acquire and share information.
Information systems	D	Platforms to integrate and process information.
Communication	E	Sharing and transferring information between people.
Situational awareness	F	Interpretation concerning the prevailing circumstances, the events that gave rise to the current situation, background information on the situation and assessments of the development of the situation, as well as the operational readiness of actors.
Prior knowledge and mental models	G	Knowledge and experiences that the individuals already have about corresponding situations. Mental model is an explanation of an individual's way of thinking about how something works.
Sensemaking	H	Active processing of information to create understanding of the situation. Inference of options by using prior knowledge and participating in social exchange of knowledge.
Decision-making	I	Choosing between the alternative courses of action. Deciding to act.
Standards and norms	J	Organisations' binding policies and procedures of action and communication.
Action	K	A physical action (an implemented decision).

with the currently available information, i.e. **data (situational picture)** (B), concerning the situation and how reliable we think this information is [68].

In the sensemaking (2) and decision-making (3) phases under the *cognitive domain*, the information is processed in light of the prevailing knowledge base (**prior knowledge and mental models** [G]) to interpret it and to consider what could be done [59]. At this point, to evaluate the viability and ranking order of the options, additional information is often needed [69,70]. Therefore, we included the possibility to return from both the **sensemaking** (H) and **decision-making** (I) elements to the awareness creation phase. The realistic and timely picture of the ongoing situation is a key role when an operational leader evaluates and ranks alternative courses of actions. The viable and recommendable options also depend on the (joint) values, standards and norms of the organisation or community [40,71]: how carefully they have been defined and how well the operational leader knows them. The concrete **action** (K) following the decision-making phase is executed in the *physical domain,* and the observations on its impact provide a **stimulus** (A) for the update of the situational picture and the next decisions and actions [59].

In emergency and disaster response operations, situations are usually complex – different response agencies observing and orienting in parallel [72,73], each bringing in their own culture, traditions, experiences, educational background, institutional structure and hierarchy and other information. Similar to Smith's [58,59] *social domain*, we have included the *social and cultural influences* that have an impact both on the *cognitive domain* and *information domain*. The latter reflects how agencies have different practises to communicate and technologies to integrate and share information. Importantly, as the framework (Fig. 2) illustrates, to ensure a shared **situational awareness** (F), **communication** (E) is needed not only when it comes to sharing data but also interpreting them. This means the cognitive process should also be shared to ensure common understanding about the ongoing situation [74,75].

3.2. A protocol to analyse the creation of shared SA and operational decision-making in cooperative disaster simulations

Following the main phases of the constructed framework (Fig. 2), the protocol is divided into four parts that are presented in this section, each comprising a set of questions and aspects to be considered (Tables 2–4) to gather information about the key elements (nodes in Fig. 2) and their interaction. For each simulation training, the first step is to select and modify the questions and issues to be observed to suit a particular exercise setup and aim. The active actors in this protocol are the agents participating (i.e. participants) in the exercise as well as the instructors and analysts of the exercise. A general structure and stages of a simulation training are presented in Appendix A.

The protocol tables (2–4) cover general analytical questions, followed by the aspects that can be monitored during the simulation and after it in a debriefing session to answer the questions.

3.2.1. Protocol part 1: awareness creation in the information domain

Although the incident or disaster occurs in the physical domain, the groundwork for the operational decision-making and response measures takes place in the information domain where the response agents are creating SA (Fig. 2). Creating SA is a constantly updating process [15,59] linked to the continuous data and information flow about the (evolving) state of the system [17].

In Table 2, one of the focus areas during the exercise scenarios is to examine how fluent the **data acquisition** (C) is. For instance, one way to evaluate this is to list what sources, platforms and tools are used to acquire data and by whom. The fluency and problems could be related to how well the persons know what data they need, where they can get them and, furthermore, how they use technical platforms and communication tools to get the information. In multi-organisational cooperation, the challenge is to synchronise the **data acquisition** (C) and **communication** (E) practises between the different organisations to coordinate and share information [31,41,76] (Fig. 2). The formation of shared SA can be hindered, for example, due to lack of shared terminology [31,39] or language [71] when the response operation involves multiple agencies or countries. Trust has an impact on how individuals communicate and share information within and between teams [10,77,78]; therefore, a lack of trust may hamper the multi-organisational cooperation [29,39,77]. Trust can be built, for example, by the means of successful and well-planned joint rehearsals [77].

As for initiating emergency response to enable effective and timely collaborative response measures and actions, the agents involved must move from the individual SA to comprehensive shared SA [29,79]. As the experts and agents in charge of the response operations must collect, produce and share situational information [69,80], it is possible for the observers and organisers of the exercise directly monitoring the training events to make an assessment on how they succeeded and reached the shared SA.

Information systems (D), create common operational pictures (COP) or situation pictures, providing real-time, spatio-temporal information to support the creation of individual and shared SA and the following decision-making [69,80,81]. In joint operations, common or synchronised information systems integrate data from a variety of sources and display those in a common presentation to the agencies [82]. Thus, sharing critical information and the formation of shared SA is delayed without the common information systems [16,29,31,39]. However, as a limitation, these systems might support only the management level and ignore the information requirements of different individuals and teams [16]. Each agent should have a high level of SA about the elements relevant for her/his responsibilities, which means it is necessarily not identical with all the other actors [38,83]. In multi-agent cooperation, common situational understanding is defined as shared understanding of the information provided by common information systems [84]. As each individual, team and agency focus on specific information that relates to their tasks and inter-

Table 2
Formulated questions and aspects concerning the awareness creation phase. The letters indicate the nodes in Fig. 2.

General analytical questions	Monitoring during the simulation scenario	Debriefing after the simulation scenario
Sources, platforms and tools to acquire data		
What data are gathered and how are data integrated to create the situational picture? (B, C, D); What kinds of differences between the participants can be observed regarding data acquisition (C)? What are the key technological issues in data acquisition (C)?	What data are acquired and how? (C); What sources, platforms and tools are used to acquire data and by whom? (C); How did the data acquisition process go? (C); If problems are detected, what are they?	How well do the participants think they performed with the data acquisition (1) as individuals and (2) as a team? (C); What challenges did they experience and how could the challenges be addressed? What should be practised more? What do they feel they did particularly fluently and why?
Platforms and tools to process and integrate acquired data to create an updated situational picture		
How are the data processed, compiled and communicated to create the shared situational picture? (B, C, D, E); What differences can be observed between the participants in how the data are processed? (D)	What platforms and tools are used to process and share data by different units and how? (D)	How well do the participants think they performed with the data processing and sharing (1) as individuals and (2) as a team? (D); What challenges did they face and how could these be addressed? What should be practised more? What do they feel they were doing particularly fluently and why?
Communication practises and tools to share data and information		
What differences between the participants can be observed in how the data are communicated? (B, E); Is the communication hindered due to a lack of shared terminology (or language) across the agencies? (E)	How are the data communicated by different agents or units, to reach a shared situational picture? (B, C, E); What type of information is shared within their own team and between the agencies? (B, E); How good is the use of the communication tools? (E); If problems are detected, what are they? How do the participants discuss about the data and observations (i.e. the situational picture)? (B, C, E)	How do the participants think they performed with the information sharing (1) as individuals and (2) as a team? (E); If problems occurred, what do the participants think were the key reasons?

Table 3
Formulated questions and aspects concerning the sensemaking and decision-making phases in the cognitive domain. The letters indicate the nodes in Fig. 2.

General analytical questions	Monitoring during the simulation scenario	Debriefing after the simulation scenario
Formation of shared situational awareness		
How is the shared SA formed? (F); What are the roles of different elements in its formation? (B, E); What are the roles of communication and data in the process and how does their interplay show up? (B, C, E, F)	Do the agents reach a consensus on the SA (i.e. is the SA 'shared') or can some disagreement be observed? (F)	How do the participants outline the aspects that affected the creation of an individual SA? Do they think they managed in reaching shared SA? (F); What do they think advanced or hindered the creation of (shared) SA?
The role of prior knowledge in the sensemaking process		
How do the individual and joint sensemaking show up and what kinds of roles do the prior knowledge of the individual participants play in it? (F, G, H); How do the participants try to solve the difficulties as a group? (E, F, G, H)	How does the interplay of prior knowledge, current data and sensemaking come up in the communication? (B, E, F, G, H); How do the participants jointly make sense of the situation (i.e. interpret what is going on) based on the available information? (B, E, F, H); Do the participants refer to their earlier experiences (rehearsals or true situations) or other sources of knowledge, while justifying their views to the others? (E, F, G, H)	What information did the participants use to make sense of the situation? (B, F, H); What additional information would have been helpful? Do they think joint sensemaking took place during the exercise? (E, F, H); If yes, when and how? Do they feel that the joint sensemaking was successful (and if not, why)? Can the participants identify points where the shared sensemaking would have been helpful (but did not occur)? Do the participants recognise points where they actively thought about their earlier experiences or studies during the sensemaking phase? (G, H); Do they feel their earlier experiences affected some of their assumptions or choices (where and how)?
Decision-making process and consensus about the decisions (actions)		
What kinds of decisions are made during the operation and by whom? (I); Where are the key points of joint decision-making (points where some important common choices negotiated are made)? (I); How does the team end up with the decisions? (E, F, H, I); Are there different views on the optimal decision? Are the decisions made in a timely manner?	Do the participants discuss alternative actions? If yes, how do they negotiate, and who negotiates with whom? (E, F, H, I); How do they end up with the final decision? How is the final decision communicated, by whom and to whom? (E, I); Is there a collective agreement about the decision, or can some disagreement or hesitation be observed? (E, F, H, I)	Do the participants feel they managed to make sense of the situation to the level sufficient for making the decisions they had to make? (H, I); What do they identify as the key joint decision-making points during the exercise (i.e. the points, where choices were negotiated and made together with the other actors)? (E, F, H, I); Who do they think were involved in these decisions and do these views match among them? Do the participants feel they always reached a consensus about what should be done (and if not, what were they disagreeing about)? In case of a disagreement, how were the final decisions made? Do the participants have any suggestions for alternative practises? Did all participants feel the right actors were informed about the decisions (before performing the action)? If not, who else should have been informed?
Standards and norms affecting the choices and actions		
How do the standards and norms affect the choices? (I, J)	Do the participants mention any (organisational, national, international, etc.) standards or norms, while negotiating the decisions? (I, J)	Are the participants able to identify, what norms and standards affected their final choices during the exercise? (I, J); Do they identify disagreements that were arising from differences in the norms and standards?

Table 4
Formulated questions and aspects concerning the execution phase in the physical domain. The letters in Fig. 2.

General analytical questions	Monitoring during the simulation scenario	Debriefing after the simulation scenario
Implementation of the actions		
What are the key response actions of the exercise and is their implementation successful? (K); What are the key reasons behind (potential) failures?	What key response actions can be recognised (by the analysts) during the exercise? (K); Do these seem to be successful (i.e. is the intended effect reached)?	What are the key response actions that the participants name? (K); Do they feel the implementation was successful (and if not, why)?
Evaluation of the implemented actions against the action plan		
Is the implementation of the key response actions in line with the decisions made? If not, what is the reason? (H, I, K)	Do the implemented actions seem to correspond to the decisions made (the action plan)? (I, K); If not, how does the implementation differ from the plan and does the reason come up (is it communicated among the participants)?	Do the participants think the executed key response actions were in line with the decisions? (I, K); If they did not fully correspond to the action plan, what were the key reasons for that? What could be changed or practised to improve the correspondence in a similar situation?
Monitoring and communication of the effects of the actions implemented		
How are the effects of the implemented response actions monitored and communicated? (A, B, C, E, K)	How do the participants acquire and communicate information concerning the effects of the actions implemented? (A, B, C, E, K)	Do the participants think they had a realistic picture of the effectiveness of the key response actions? (A, B, K); If not, how could it have been improved? How did the picture they got (i.e. the new updated SA) affect their next choices?

pret the situational data based on their differing prior experiences and consequential mental models, even a functioning information system does not assure that a common situational understanding is achieved. Additionally, mutual understanding of each other's operational systems is required, accompanied with respect and trust, as well as common tools and practices for information sharing and communication.

3.2.2. Protocol part 2: sensemaking and decision-making phases in the cognitive domain

When people face uncertain, chaotic or unexpected situations, they need to make a (new) sense of their environment [85,86]. **Sensemaking** (H) during disasters is about building understanding of a situation by making observations and integrating and interpreting these observations [87–89]. It is a cognitive process, where the acquired information is contextualised in terms of the **prior knowledge and mental models** (G) [59,88,90–92]. However, it is not a static state but is shaped by people's experiences and actions [93].

During disaster simulations, monitoring the processes that take place in the cognitive domain is difficult, as many of them take place inside participants' minds. For instructors and analysts of the exercise to understand these processes and their causal relationships, it is particularly important to ask participants to explain their activities and trains of thought during the debriefing (Table 3). Thus, to understand how the cognitive processes and human mind work in an emergency and disaster situation, we will discuss the two models of information processing: System 1 denoting the intuitive system, which is typically fast, automatic and nonconscious, and System 2 denoting reasoning that is analytical, slow, controlled, conscious, logical and effortful [94–97]. There is no strict boundary between intuitive and analytical thinking, as these two systems are said to interact seamlessly together [98]. They work either sequentially, where the first intuitive responses to judgment problems are then monitored and corrected by the analytical model [99], or in parallel and are used differently according to the nature of the **decision-making** (I) situation in question (e.g. Refs. [100,101]).

During the simulation scenarios, listing the observable key decisions helps analysts to assess what types of decisions have been made and how they have been attained. By going through the key decisions listed, the analyst can ask participants to explain how a particular decision was reached and what processes were used (Table 3). For instance, the Recognition-Primed Decision (RPD) model is used to explain how leaders with a high level of expertise can make fast decisions without using a lot of time by comparing all the options [102]. In the RPD model, leaders use their experience to create a mental model to visualise the outcome of the action by using an intuitive system. Rather than going through all the possible options, experienced actors select the first workable option. Hence, if the situation is new, the processing will take more time and effort. Second, by using System 2, the options proposed by System 1 are evaluated [90].

As intuitive way of thinking works based on experience and heuristics, and highly skilled agents may rely more on intuition in the **decision-making** (I) process [103,104], even ignoring signals that are unfamiliar [105]. In **decision-making** (I) during disaster management, when fast decisions are needed, intuitive processing might be a useful approach but only when that intuition has been practised through lots of experience or repeated exercises [103]. In acute disaster operations, agents are often exposed to episodic events that threaten the predetermined management of the event [106]. Therefore, agents must revise predetermined plans and adapt to make real-time decisions to prevent or mitigate undesirable consequences [33,105,107]. More experienced agents adapt more easily to changing situations than those with less experience of different situations [105]. However, to detect these aspects during emergency and disaster simulations, analysts need to know in advance the participants' backgrounds and levels of experience (Appendix B).

Disaster and emergency response is usually characterised by ambiguity as it deals with situations in which there is a lack of **prior knowledge and mental models** (G) [108]. In group decision -making, a cognitively diverse group of participants can create more wide-ranging and effective contributions towards the problem [108]. However, to act effectively in an emergency, a good understanding of the roles of the different agents, both within and between groups, is required [109]. This also helps to make better use of skills and competences of the participating agents [110].

In the event of a large-scale emergency, decisions are made in extremely challenging environments, where time is limited and stakes are high [111]. These types of high cognitive load conditions, in which several simultaneous decisions must be made quickly, may lead to cognitive overload and human errors [112]. In this case, the ability for cognitive flexibility, which is the ability to move smoothly from the big picture to the detailed side of the situation, is important. Here, too, the level of experience of the participant is relevant, as less experienced actors may focus on building the **situational awareness** (F) and hesitate too long to make actual decisions. High levels of cognitive load can use working memory capacity, which can therefore impair the ability to make effective disaster management strategies [113]. In the framework (Fig. 2), the concept Situational awareness represents the situational understanding resulting from of the interplay of the awareness creation and sensemaking processes. It arises from the data-based situational picture and the interpretation of the data, communication playing an important role in terms of both, especially when common (i.e. shared) situational understanding (i.e. awareness) is to be reached.

3.2.3. Protocol part 3: execution of the actions in the physical domain

When a decision is made and put into action, it is important to monitor and evaluate the implementation of the selected **action** (K) [114,115] (Table 4). Implementation may fail if the agreed management strategy is not followed, or if the use of equipment or measure does not work as it should. If the SA on which the **decision-making** (I) was based is no longer valid (e.g. as circumstances or weather conditions abruptly change), the functionality of the initial strategy will be impaired. Additionally, in decision-making during disaster management, experts rely heavily on their own **prior knowledge and mental models** (G) [90]. Thus, disagreements between the agents who lead the operation over how to interpret the situation can cause reluctance to adopt a decided strategy [27]. Therefore, if the implementation of the **action** (K) does not go as it should, it is important to find out the reasons for further exercises as well as for real emergency and disaster response.

3.2.4. Protocol part 4: background information on social and cultural factors

In Fig. 2, *Social and cultural influences* underlie as cross-cutting background factors of the developed framework, covering, for example, the participants' educational background, level of experience, organisational culture and mutual hierarchy, as well as psychosocial skills and stress tolerance [30,67,103–105,116]. The listed aspects represent such *social and cultural influences* that can have remarkable impact on the various elements (nodes) of both the *cognitive domain* and the *information domain* (Fig. 2).

Thus, pre- and/or post-training surveys that focus on the socio-cultural background aspects are recommended to conduct as part of the suggested analysis protocol. However, the relevance of different aspects and thus the content, timing and method of the surveys should be considered case-specifically. Table B1 (Appendix B) shows some potential example questions for considering educational and organisational background aspects in pre- and post-training surveys to elaborate their potential impacts on the participants' ways of action and performance during the simulation. It is notable that the background questions typically are of such a nature that the anonymity of the respondents must be carefully guaranteed. The anonymisation improves the likelihood of honest answers [117].

3.3. Preliminary experimentation

The first test-use of the protocol was in May 2022, in the context of an oil combating training organized for response agencies in a virtual simulator environment. We monitored a spill reconnaissance exercise (searching and locating a spill) followed by an exercise where the spreading of a spill was limited using oil booms. Both tasks were conducted as a joint effort of three teams, located in two vessels at sea (distinct simulator rooms with a realistic bridge and a simulated view behind the windows), and in a command centre (a separate classroom). Fig. 3 illustrates the exercise setup. In the following, we provide a general description on how we utilized the protocol and make some remarks on our user experience. However, in this article we do not go to the content analysis of the exercise.

Prior to the exercise, based on its manuscript and learning objectives, we selected the case-specifically most relevant questions of the protocol (the protocol column *Monitoring during the simulation scenario*) and collected them on one form. This set of questions was provided to the observers of the exercise (N = 5, including M.L.-P. and A. Le. With three external observers), who were instructed to familiarise with the questions and, paying special attention to the questions, mark down a timeline of the key events and the communication between the participants in the room they were located. Accordingly, the debrief discussion was built on the same set of questions (the protocol column *Debriefing after the simulation scenario*) by A. La., M.L.-P. and A. Le. The discussions in all the three rooms, and during the common debriefing session, were also audio recorded. Afterwards, M.L.-P. conducted individual post-exercise interviews to map the participants' educational and experience background and their personal learning experiences during the exercise. The notes of all the observers were combined to form one coherent timeline describing the course of events during the exercise, after which the observations were validated and augmented based on the audio recordings. This material was then used to answer the selected analytical questions in the protocol column *General analytical questions*.

Our experience is that the protocol guided us to focus on observing the key aspects and to ask the right questions (both from ourselves and from the participants) related to the successes and failures of the iterative SA creation – sensemaking – decision-making – action cycle. It also helped us to clearly inform three other observers coming from outside of the authoring team what they specifically should look for. The protocol served as a useful tool throughout the whole process: (1) in the preparatory phase, (2) when the simulations were observed, (3) during the debrief session, (4) while planning the post-exercise interviews of the learners, and (5) when the materials were analysed. The analysis provided information on the performance and training needs of the participating team, but also the exercises *per se*.

4. Discussion and conclusions

By synthesising knowledge from earlier scientific literature, we presented a systemic framework to represent the process of operational decision-making, describing particularly the role of the shared SA creation as part of the process. The framework was translated to an analysis protocol to be applied in a variety of emergency and disaster preparedness simulation trainings, to support the develop-

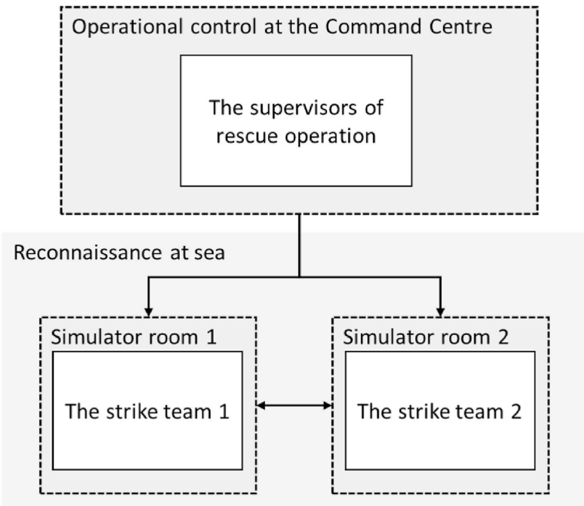

Fig. 3. Illustration of the exercise setup.

ment and harmonisation of the multi-agent and multi-organisational preparedness exercises and further on to improve the future real emergency and disaster response competence. The protocol covers all the elements of the framework, consisting of (a) the general analytical questions of interest and the suggested formulation of the questions to (b) support the monitoring of the participants' behaviour during the simulation, as well as (c) to be discussed with the participants in debriefing sessions. In addition, general instructions and ideas for acquiring information about the case-specifically relevant socio-cultural background information from the participants were provided.

The lack of trust in multi-organisational response operation can hinder communication and reduce collaboration [118], and joint trainings are said to increase trust [118,119] by allowing the response agencies to practise together and to get to know each other's practises and tools [11]. Interaction with other actors in multi-organisational groups has been suggested to promote deep learning and real-life cooperation [120]. The collaborative simulations can be assumed to provide directly for three of the decision-making training aspects listed by Khorram-Manesh et al. [120], namely: (2) *comparing the collaborating organisation's rules, roles and routines during the decision-making and making them transparent to the participants*, (6) *testing different strategies of decision-making, which is seen to improve the collaborative ways to make decisions during the actual crisis work* and (8) *using scenarios challenging the decision-making among and between the various organisations and professions*. In addition, the trainings can indirectly support other aspects mentioned in the list by Khorram-Manesh et al. [120], covering, for example, collaboration to stimulate the practise of common decision-making across professions and organisational boundaries as well as clarification of the role distribution between the participants. However, to verify whether an exercise really has the above-mentioned functions or whether it supports the listed aspects, validation through carefully planned and justified monitoring is required.

The monitoring protocol we have presented provides a formal, science-based toolkit to support the monitoring, analysis and development of the performance and learning experience of the actors attending the preparedness trainings. It is intended to help instructors and analysts to (1) document the operational reasoning and practises of actors, (2) monitor the communication and creation of the SA among actors, (3) advance knowledge sharing among the actors to promote formation of shared SA, (4) develop participants' intuitive decision-making skills, e.g. evaluate the value of waiting for additional information before making decisions under varying conditions, given time constraints, and (5) assess the effectiveness and purposefulness of the exercises and identify future training needs.

The suggested protocol can be applied to a wide variety of disaster management simulations of different types (e.g. tabletop exercises, virtual simulator environments, field exercises) and in different contexts (e.g. chemical incidents, wildfires, tsunamis), as the protocol covers the key themes and elements that are common for all disaster response scenarios, where shared SA and decision-making processes are in focus. The protocol covers a wide variety of aspects and questions, and the idea is to utilise it selectively, adjusting the selection of questions analysed case-specifically. The present work was originally conducted with only acute operational disaster response exercises in mind. However, elaborating on the potential implementation of both the framework (Fig. 2) and the analysis protocol, it seems that these tools could be applicable also in the 'Policy Operation Room' type of long-term crisis simulations suggested by Hukkinen et al. [121].

The literature review we conducted to build the systemic framework describing the operational decision-making process and the role of SA during disaster management (Fig. 2 and Table 1) took a semi-systematic approach combined with the snowball sampling that allows to select strategically articles to discover new findings and explore ideas and thus, to address broader questions [52]. As our approach was iterative, we added more search terms during the process. Naturally, the result of this approach cannot be presented as an all-encompassing review. Our focus was first and foremost in framing: in the horizontal mapping of the dimensions and concepts related to the topic. Realising the cross-disciplinary nature of the question leading to a wide and heterogeneous terminology, we made a conscious choice not to aim for a systematic literature review, the purpose of which is to map all published knowledge, revealing the state-of-the-art of research, deep lighting an already well-framed topic (see e.g. Refs. [50,52]). The systematic approach requires pre-definition of the search terminology and strategy. Iterative updating of these is allowed but fairly limited due to the fact that each change requires starting the search and screening process from the beginning. The selected topic is widely studied in different disciplines and has been conceptualized in a different ways, therefore, the semi-systematic approach offered flexibility to address more extensive questions and pursue new insights during the process. However, the present work provides a reasonable framing and vocabulary that can be used e.g. as starting point for a systematic literature survey.

During the first test-use of the developed protocol, we experienced it helped us to systematically analyse and identify what domains, elements, and processes of the SA-decision-making framework (Fig. 2) were in a key role in each phase of the exercise, promoting or inhibiting the successful operation. This information is highly useful when planning future training programmes. However, it is notable that this was only one test conducted in one context and training environment and by the developers of the protocol themselves. More testing is needed in different contexts and by subjective users before it is possible to evaluate the level of general validity and applicability of the suggested framework and protocol. We believe the protocol can be applied flexibly in various context and encourage the interested readers to creativity. An electronic platform with user interface could also be an idea worth consideration to ease the use of the protocol, and to draw together and document the observations and analytical results in a structured manner.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2023.103544.

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