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Improving situation awareness in crisis response teams: An experimental analysis of enriched information and centralized coordination

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ABSTRACT

In responding to an emergency, the actions of emergency response teams critically depend upon the situation awareness the team members have acquired. Situation awareness, and the design of systems to support it, has been a focus in recent emergency management research. In this paper, we introduce two interventions to the core processes of information processing and information sharing in emergency response teams to analyze their effect on the teams' situation awareness: (1) we *enrich* raw incoming information by adding a summary of the information received, and (2) we channel all incoming information to a *central coordinator* who then decides upon further distribution within the team. The effect of both interventions is investigated through a controlled experiment with experienced professional responders. Our results show distinctly different effects for information enrichment and centralization, both for the teams and for the coordinators within the team. While the interaction effects of both conditions cannot be discerned, it is apparent that processing non-enriched information and non-centralized information sharing leads to a worse overall team situation awareness. Our work suggests several implications for the design of emergency response management information systems.

1. Introduction

Fast-burning crises cause considerable local disruption and losses; yet, they are terminated within a short time frame after their sudden onset ('t Hart and Boin, 2001). Power-blackouts, traffic accidents, industrial accidents, forest fires or winter storms are examples of such fast-burning crises. Particularly in densely populated and highly industrialized regions, fast-burning crises carry the risk of rapid propagation and escalation (Pederson et al., 2007). When critical infrastructures such as transportation, communication or power systems are disrupted, even for a short time, large regions can be impacted and incur important economic losses (Chang et al., 2007; Merz et al., 2013). To prevent harm to the population, environment and economy, fast and effective response is crucial (Körte, 2003; Van Den Eede et al., 2006).

In a fast-burning crisis, responders are confronted with time pressure, complexity and uncertainty (Drennan and McConnell, 2007). The complexity of a crisis increases with the number of decision-makers and stakeholders involved (Rao et al., 1995). Depending on the scope of the crisis, responders need to work with experts from affected industries, policy-makers, the media, the population in the affected areas, transportation providers, and possibly many other stakeholders. Related to both time pressure and complexity is the level of uncertainty. The uncertainties around fast-burning crises are largely epistemic (Jakeman et al., 2010; Paté-Cornell, 2002), i.e., in principle they can be reduced by further measurements and analyses. However, the higher the time pressure, the less time there is for data collection; and the more complex a problem is, the longer it takes for data processing and analysis. Although a reduction in uncertainty leads to better situation awareness (Lipshitz et al., 2001; Weick, 2010; Endsley, 1995; Klein and Klinger, 1991; Kahneman, 2003; Muhren et al., 2008), the options to reduce uncertainty are often limited. Several researchers have also stressed the importance of creativity and creative improvisation for emergency responders to generate a response when unanticipated events develop (Mendonca et al., 2001; Kendra and Wachtendorf, 2007).

In an environment characterized by time pressure, complexity and uncertainty, the main challenge for a response team is to obtain as quickly as possible "situation awareness", i.e., an assessment of the extent of the crisis they respond to. The teams' situation awareness critically depends on the information that is acquired and shared within the team. Ideally, the information

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acquired by team members is easy to understand, fast to process and includes clear cues that trigger action. Moreover, the information is also efficiently shared within the team so that collectively the team can make decisions based on better situation awareness.

The prevailing *modus operandi* in response teams, however, is that information is often "raw" and unprocessed: typically, information is collected by individual team members who focus on their specific discipline or expertize (e.g., fire fighters, police, and medical care). This workflow however makes it difficult for the other team members to process and interpret the information, impeding effective information sharing. The main contribution of this paper is that we build upon suggestions in literature (Rimstad et al., 2014; Scholtens et al., 2014; Wolbers and Boersma, 2013) to investigate two possible improvements to this default state: (1) we provide *enriched* information to the response team, and (2) we *centralize* information sharing via a coordinator in the team. By means of a controlled experiment, we contrast these two possible improvements to the existing situation and evaluate the impact on the teams' situation awareness.

The remainder of this paper is organized as follows. We motivate our approach by providing essential background on information richness and centralization in Section 2 and on situation awareness in Section 3. In Section 4, we present our research approach and the hypotheses on situation awareness that we subsequently experimentally test with professional responders. The experimental design is described in Section 5, and our findings on situation awareness are presented and discussed in Section 6, respectively for team members, coordinators and observers. Section 7 discusses the impact of our findings on key design premises for emergency response management information systems. Finally, we summarize our findings and offer our conclusions in Section 8.

2. Enriched information and centralized coordination

Crisis response teams need timely information that is relevant to address the specific problem they are focusing on. According to the International Federation of the Red Cross and Red Crescent Societies "*The right kind of information leads to a deeper understanding of needs and ways to meet those needs. The wrong information can lead to inappropriate, even dangerous interventions.*" (IFRC, 2005). Yet, due to the interplay of time pressure, complexity and uncertainty, relevant information that would trigger intervention may not be available to those who need it (Turoff et al., 2004). What information is of concern and interest is changing rapidly and constantly. Simultaneously, the actual situation and the information about it evolve in a highly dynamic way, and the match between situation and information is far from perfect: information is typically lagging, uncertain, sometimes contradictory or missing, and in many cases it requires further interpretation (Comes et al., 2015). In other words, the dynamics of a crisis and the volatility of the situation, the information about it, and the aims organizations or individuals pursue impact the effectiveness of coordination (Comes et al., 2011; Van de Walle and Turoff, 2008).

2.1. Information richness

Information and technology are an inherent part of todays' work processes in the emergency response services. To produce informational products and/or services for internal or external customers, emergency response services make use of information systems, i.e., systems in which human participants and/or machines perform work using information, technology, and other resources (Alter, 2008). Information systems can process, filter, recombine and aggregate information to provide suitable interpretations such as summaries, averages, comparisons, or extrapolations to enhance the value of information for the intended user and usage (Miller, 1996). In doing so, however, information systems may introduce additional problems: "*The problem with information systems is that representations in the electronic world can become chaotic for at least two reasons; the data in these representations are flawed, and the people who manage those flawed data have limited processing capacity*" (Weick, 1985). More recently, Wolbers and Boersma (2013) have argued for a switch from an information warehouse system towards a "*trading zone*" where information is discussed and evaluated collectively. This, however, requires active engagement and time, a resource which is in short supply in fast-burning crises.

Literature on what constitutes data and information quality (with the former mostly referring to technical, and the latter to non-technical aspects) is highly diverse. Many authors emphasize the dependence of information quality on a context across user and information perspectives (Ge and Helfert, 2007; Wingkvist et al., 2010). Particularly in crises, the context and situation can impose extreme conditions on users and systems that influence the quality of the information (Van de Walle and Turoff, 2007). Wang and Strong (1996) propose to differentiate between context dependent and context independent attributes and intrinsic, problem-centered, and representation criteria (Ge and Helfert, 2007; Wand and Wang, 1996; Wingkvist et al., 2010).

Table 1 provides an overview of the most important information characteristics that we will use in this paper. Commonly, context independent attributes are described as criteria for information quality. For instance, more complete information has been considered of higher quality (Wang and Strong, 1996). Information richness, however, is constituted from context dependent attributes. In their seminal work, Daft and Lengel (1984) define information richness as "*the ability of information to change understanding within a time interval*", and they claim that organizational success is based on the organization's ability to "*process information of appropriate richness to reduce uncertainty and clarify ambiguity*". In addition to problem-centered attributes such as relevancy or timeliness, the capacity to change the understanding of a problem in a short time depends on the representation of information (see Table 1). Particularly in situations of stress and time pressure the ease of understanding and clarity of information is crucial (Maule et al., 2000).

Media richness theory, also referred to as information richness theory, states that communication media vary in their "richness" or their ability to help users understand a problem (Daft and Lengel, 1986). Several authors have emphasized that creative tasks, or tasks that involve the discovery of unknown problems require relatively low information richness (Hollingshead et al., 1993; Saunders and Miranda, 1998; Straus and McGrath, 1994). Adequate information richness depends on the time available, the skills of the decision-makers and the novelty of the problem: rich information by itself is not sufficient for achieving understanding.

While information can be enriched in various ways, we define in this research "enriched information" as information that

Table 1
Categorization of information quality attributes.

	Context Dependent Attributes	Context Independent Attributes
Intrinsic	Credibility, Reputation	Accuracy, Objectivity
Problem-Centered	Value Added, Timeliness, Relevancy, Appropriateness	Completeness
Representation	Interpretability, Ease of Understanding	Consistent and concise representation

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combines information from different sources and is represented in a format with which professional crisis responders are familiar. Information that is *not* aggregated nor represented in a specific format is considered “raw” or non-enriched. As an illustration of the difference between raw and enriched information, consider the example of a train accident: raw information is the information about the carriages that comes in (via the responders in the field) at irregular times. Enriched information consists of a summary the coordinator provides to the team with an overview of all the carriages and what is known about them at that moment.

2.2. Centralized coordination

In their influential 1985 article, Stasser and Titus (1985) demonstrated that group discussion is a poor means of exchanging information that is not commonly shared by all members of the group. Their introduction of the hidden profile paradigm, focusing on tasks that involve the discovery of a hidden optimal decision, gave way to an impressive body of research on conditions, processes, and decisions associated with such tasks, mostly confirming that groups do not exchange information efficiently yet focus on information that is known and common to all group members, and that decision quality suffers as a result (Lu et al., 2012). In earlier research, we found evidence of this common information bias in humanitarian crisis response teams (Muhren and Van de Walle, 2010; Muhren, 2012). Several researchers have attempted to reduce this bias, for instance by designating group members as experts in a specific domain or by appointing team leaders. While these treatments reduced the bias, groups still discussed significantly more common than unique information (Stasser et al., 1995; Larson et al., 1998).

As much as there is the need for sharing relevant information during a crisis, it is as crucial to achieve rapid and coherent coordination among those responding to a crisis (Chen et al., 2008). Coordination here is understood as distribution of tasks and allocation of resources (Comfort, 2007; Schryen et al., 2015). Clearly, coordinating the different response organizations brings an additional cost of attention and effort, and coordination breakdowns during a crisis are well documented. Reasons for such breakdowns include a lack of history in working together, differences in workload and priorities, communication disruptions and lack of monitoring (Klein et al., 2005).

In order to accomplish effective response, teams typically divide tasks and assign components to different team members, requiring *internal coordination*. When the division of labor requires joint effort of several organizations, such as fire fighters, police or medical services, the need for *external* coordination arises as prioritization and distribution of tasks *across* organizations is now required. Typically organizations focus on their own challenges and in doing so often use their own jargon, making a common understanding and hence external coordination difficult (Heath and Staudenmayer, 2000). While typically a lot of attention is paid to an efficient initial division of tasks and task assignment, the equally important tasks of monitoring, sharing information, and updating tasks and their distribution in teams is often neglected (Schryen et al., 2015; Zook et al., 2010).

In this paper, we introduce a treatment by directing *all* incoming information towards a dedicated team member (the coordinator) who subsequently re-distributes this information within the team, taking into account the expertize and tasks of the team members. We refer to this setting as the “centralized coordination” setting. The setting in which the individual team members receive and distribute information will in the remainder of this paper be referred to as the “de-centralized” setting.

3. Situation awareness

Endsley defines situation awareness as “*the perception of the elements in the environment* […], *the comprehension of their meaning and the projection of their status in the near future*” (Endsley, 1995). This definition considers three levels of situation awareness: perception (level 1), comprehension (level 2) and projection (level 3), with the success of the higher depending on the success of the lower levels (Endsley, 1995; Wickens, 2008). In turn, projections, expectations and understanding of the situation have been demonstrated to influence perception and comprehension (Camerer and Kunreuther, 1989; Tversky and Kahneman, 1986; Wright and Goodwin, 2009) and as such all levels are interconnected. When teams make decisions and act upon them, an overall *team situation awareness* can be conceived as the degree to which every team member possesses the situation awareness required for her or his responsibilities (Endsley, 1995).

A number of techniques have been developed for measuring situation awareness, one of which is the Situational Awareness Rating Technique (SART) (Taylor, 1990). SART is based on a person's subjective opinion (Endsley et al., 1998). More specifically, a person's situation awareness is rated on three 7-point Likert scales, measuring the degree to which that person perceives (i) the demand on attentional resources (D), (ii) the availability of attentional resources (A), and (iii) the understanding of the situation he or she is confronted with (U). The demand D depends on factors such as the current situation's stability, complexity or variability. The availability of attentional resources A is affected by the person's degree of alertness, concentration, and spare mental capacity. Understanding of the situation U is influenced by the available information quantity and quality, and the familiarity with the situation. SART then defines situation awareness (SA) as

$$SA = U–(D–A),$$

with SA taking values in the interval $[-5, 13]$. In our study, we measure the situation awareness of crisis response teams as well as of the team coordinators. Focusing on these different roles enables us to compare the load and resulting situation awareness, and draw conclusions that take into account the specific challenges for each role. In addition, we contrast this internal perspective with SART assessments of observers who did not participate in the exercises but were asked to assess the teams' performance. While observers are frequently used to rate a team's situation awareness and to provide non-intrusive feedback, the extent to which observers can accurately rate the SA of teams or individual team members has often been questioned (Matthews et al., 2011; Salmon et al., 2006).

4. Research approach

Our main research objective in this paper is to experimentally test the impact of information richness and information centralization on the situation awareness of crisis response teams. As information richness is as “*the ability of information to change understanding within a time interval*” (Daft and Lengel, 1986), we expect that providing enriched information to the crisis response team members will lead to a better understanding of the crisis situation, as compared to providing raw information. As such, we hypothesize that:

H1. The use of enriched information leads team members to attain higher situation awareness as compared to the use of non-enriched information.

By directing the information inflow towards a dedicated team member, or centralizing the information, we expect that this team member will be able to readily recognize important and unique information and share this with the rest of the team. Compared to non-centralized conditions, we therefore expect that centralized teams will attain higher situation awareness. We thus hypothesize that:

H2. Team members that work in centralized conditions attain higher situation awareness than team members that work in decentralized conditions.

We also expect a synergetic effect of enriched information and centralized information sharing on situational awareness:

H3. There is a positive interaction effect among information enrichment and information centralization leading to higher situation awareness for the team members.

Since coordinators are central to the active management of workload in complex and dynamic fast-burning crises involving distributing workload over time and across resources, we are particularly interested in their situational awareness. While all team members require an adequate overview of the wider situation to guide their own contribution to the team's work, a coordinator must integrate more knowledge in order to perform as focal point (Mackintosh et al., 2009).

As for team members, we expect that also the coordinators' situation awareness is improved if they receive enriched information:

H4. Coordinators that use enriched information attain higher situation awareness than coordinators that use non-enriched information.

In centralized settings, all information is routed via the coordinator who determines how the information shall be distributed to the team members. Therefore, we expect that in centralized conditions the demand becomes so high that it *decreases* the coordinators situation awareness as compared to the decentralized conditions:

H5. Coordinators that work in centralized conditions attain lower situation awareness than coordinators that work in decentralized conditions.

Since the hypotheses H4 and H5 imply opposed impact of information enrichment and centralized information sharing on the coordinator, we hypothesize that there is no positive interaction effect for the coordinators.

H6. There is no positive interaction effect among information enrichment and information centralization leading to higher situation awareness for coordinators.

Although literature is sparse, there is some previous work that suggests that team members in situation of stress and time pressure tend to rate their situational awareness higher than the observers do, and that the observers are not able to capture the differences and nuances of the team members' situational awareness (Matthews et al., 2011). Therefore, we hypothesize:

H7. Observers will rate the team members' situational awareness significantly lower than the team members themselves.

In the next Section, we detail the experimental set-up for validating the Hypotheses. Based on the experiments conducted, Section 6 discusses our findings on the situation awareness. The results for the team members are provided in Section 6.1, for coordinators in Section 6.2 and for the observers in Section 6.3.

5. Experimental design

In this section, we provide information on the experimental task (Section 5.1), the participants and procedures (Section 5.2), and the treatments administered and measures used (Section 5.3).

5.1. Task

Participants in the experiment were tasked to respond to two cases of a fast-burning crisis. The participants were informed that the case descriptions were fictional, but they were asked to respond to it to the best of their professional abilities, as in any of their regular table-top exercises and trainings. The crisis response teams received textual and audiovisual operational information on the crisis and were asked to deal with the problems that emerge as the crisis develops. The scenarios for both cases were built by the research team (consisting of academic researchers and experienced practitioners) and were validated by independent and experienced crisis managers to ensure an appropriate level of difficulty and realism. The scenarios were chosen such that risks and effects of the crises were recognizable and realistic for all participants.

The first case is a train accident leading to the release of hazardous materials in a residential area. In this case construction workers are working on the railroad and due to a communication error a train passes through the working area and derails. Multiple carriages are tipped over and their content is leaking. In total the train has 20 carriages and 5 of them contain liquids and hazardous materials. The train derails in the proximity of three residential areas and next to a public park. In the nearby park, an event of the local boy scouts is taking place. Approximately 44 boy scouts are in the park, some of whom are missing. The crisis response team has to deal with the hazardous materials and leaking content, but also with the effect of the derailment on the boy scouts event, the residential area and even with the possible longer term effects on the environment.

The second case concerns a party in a local bar, attended by 250 people. Following a fight inside the bar, four people are expelled, yet they return after half an hour and throw a Molotov cocktail into the bar. A fire starts and spreads rapidly through the building, causing massive panic. Most people can escape, yet many of them suffer from severe burns. About 30 people are still missing. Sometime later still, an explosion occurs and one firefighter is injured in the explosion. The crisis response team here has to deal with a large number of victims and an act of violence of which the culprits are still on the run. The explosion and the injured firefighter add to the complexity of the crisis.

5.2. Participants and procedures

Participants in the experiment were emergency managers and police, fire and medical officers who were selected on the basis of their training and their active participation in actual crisis response over the past two years. We did not retain inexperienced and junior crisis managers or very senior crisis managers, as we were targeting participants with a similar level of experience. Participants were assigned to a crisis response team, consisting of four members: one general coordinator and three commanding officers responsible respectively for the police, fire and medical services. The participants were assigned to roles in the team that correspond to their professional roles. The role of general coordinator could be assumed by a participant from any of the three services, as is defined in the Belgian emergency response legal framework. In addition to the crisis response team, two external observers were present during the experiment. The external observers were professional crisis managers, yet more experienced

Table 2
Experimental design.

Information centrality	Centralized	Decentralized
Information richness		
Not enriched	4 Teams	4 Teams
Enriched	4 Teams	4 Teams

and in many cases full time crisis managers.

The experiments were held in eight separate half-day sessions and conducted at three different Belgian Fire and Rescue Training Schools. In each session, two 50-min long experiments were held, with 4 participants each. All teams received a 10 min briefing to explain their role in the experiment. Throughout the experiment, inputs or situation updates were provided to the participants. In traditional exercises, these inputs are often provided manually, yet for our experimental purposes we made use of commercial simulation software to automate this process. The software simulates pre-programmed inputs from the commanders in the field, from strategic command and from the media. The simulator can provide text, images, movies and audio as inputs, at a pre-determined time or within certain time intervals.

5.3. Treatments and measures

The teams were assigned to one of the treatment conditions of information richness (enriched versus non-enriched) and information centralization (centralized versus decentralized) in a typical 2×2 experimental design as shown in Table 2.

As discussed above, SART defines situation awareness as $SA = U-(D-A)$, with U the understanding, and D and A the demand on and availability of attentional resources, respectively. Although SART is typically measured after the experiment, we decided to measure SA as the experiment was on-going. The exercise was therefore every ten minutes shortly paused for one minute to allow every team member to rate his or her situation awareness at that moment. The observers were asked at the same moment to score the team's shared situation awareness, as they perceived it. In total 16 experimental sessions were conducted, four in each of the conditions. In every session, all four team members, as well as two observers, were asked to score the SART test in five ten-minute intervals. Assuming that the SA at each point in time is equally important, in total, 4 (teams) $\times$ 6 (team members and observers) $\times$ 4 (conditions) $\times$ 5 (measures) or 480 individual situational awareness measurements were obtained.

5.3.1. Information richness

For the "information richness" treatment, one condition offers enriched information, whereas the other condition provides for raw information. In the condition where information is enriched, a summary of the situation is being provided to the crisis response team every five minutes. The summary consists of information that the team already received and adds no new information.

5.3.2. Information centrality

For the "information centrality" treatment, in one condition information sharing is centralized, whereas in the other condition it is decentralized. In the centralized condition, the team receives all information through a coordinator; in the decentralized condition each member of the team receives specific information for his or her role, *except* the coordinator. While in the centralized setting team members have to rely on the coordinator, in the decentralized setting situation awareness can be acquired by communication with the coordinator or across team members.

5.3.3. Measures

The variables we used and the constructs they measure are presented in Table 3, and discussed below if they were not previously mentioned.

6. Findings on situation awareness

In this section, we present the experimental findings on the situation awareness of the different participants in the experiment. We first focus in Section 6.1 on the team members, and provide an analysis of their situation awareness as well as the underlying dimensions of availability, demand and understanding. Section 6.2 focuses on the coordinators separately, as they have a crucial role in the team. The observers, who are not part of the team but have participated in the exercise, provide for an external perspective on the teams' performance. The observers' results are discussed in Section 6.3.

6.1. Situation awareness of the team members

As indicated earlier, a team consists of three commanding officers for fire, medical, and police, and a coordinator. Table 4 lists the means and standard deviations of the situation awareness (SA) and its dimensions (D, A, U) for the different roles in the different conditions. Recall that we have 4 teams per condition, each with 4 members, and that SA (and similarly D, A and U) is measured five times during the experiment, so we have in total 80 measures of SA per condition.

A one-way ANOVA was conducted to compare the effect of the treatments on team members' situation awareness as well as on the underlying dimensions of availability, demand and understanding. The results are shown in Table 5.

The ANOVA shows that there is a statistically significant effect of information enrichment and centralization on situation

Table 3
Variables definition and measurement.

Construct	Variable	Type	Variable Description	Variable Measurement
Information richness	Information richness	Nominal: dichotomous	Richness of information provided, which was either enriched or not (raw)	0 = Raw 1 = enriched
Information centralization	Information centralization	Nominal: dichotomous	Information was either centrally collected, or distributed among all team members (decentralized)	0 = Centralized 1 = Decentralized
Situation awareness	Demand	Interval: continuous	Level of demand on attentional resources	7 Point Likert scale
	Availability	Interval: continuous	Availability of attentional resources (perceived workload)	7 Point Likert scale
	Understanding	Interval: continuous	Understanding of the situation provided	7 Point Likert scale
	Situation awareness	Interval: continuous	Situational awareness attainment	Understanding score − (demand score − availability score)

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Table 4
Descriptive Statistics of *SA* and its Dimensions *D*, *A* and *U* for the four conditions (*N*=80).

Roles	Mean *SA*	SD *SA*	Mean *D*	SD *D*	Mean *A*	SD *A*	Mean *U*	SD *U*
Decentralized not enriched								
Fire	4.5	2.87	5.3	1.03	4.45	1.47	5.35	1.18
Medical	3.85	2.78	5.5	1.15	4.65	1.66	4.7	1.49
Police	3.05	1.85	4.7	1.08	4.1	1.52	3.65	1.18
Coordinator	2.3	2.45	5.35	1.14	3.8	1.91	3.85	0.99
Average	3.43	2.49	5.21	1.10	4.25	1.64	4.39	1.21
Decentralized enriched								
Fire	5.2	2.33	4.75	1.59	4.9	0.91	5.05	1.1
Medical	4.3	1.38	5.25	0.79	4.85	0.81	4.7	0.8
Police	3.05	3.36	5.35	1.31	4.05	1.28	4.35	1.46
Coordinator	4.65	2.43	6	0.97	5.35	1.18	5.3	1.13
Average	4.30	2.38	5.34	1.17	4.79	1.05	4.85	1.12
Centralized not enriched								
Fire	5.9	2.88	4.15	1.23	5.25	1.21	5.25	1.54
Medical	4.05	1.76	4.85	1.09	5.05	1	5.05	1.39
Police	5.25	2.02	4	1.41	5.1	0.64	5.1	1.04
Coordinator	3.7	3.26	5.6	1.27	4.15	1.81	4.15	1.35
Average	4.73	2.48	4.65	1.25	4.89	1.17	4.89	1.33
Centralized enriched								
Fire	3.75	4.48	5.25	1.37	4.50	1.67	4.50	1.76
Medical	6.05	1.39	4.35	0.75	5.85	0.75	4.55	1.05
Police	3.40	2.09	4.70	1.42	3.85	1.14	4.25	1.48
Coordinator	0.70	3.71	6.75	0.44	3.75	2.10	3.70	1.81
Average	3.48	2.92	5.26	0.99	4.49	1.41	4.25	1.53

Table 5
Anova analysis of SA and its dimensions.

		Sum of squares	*df*	Mean square	*F*	Sig.
Situation awareness	Between groups	98	3	32.55	3.86	0.010
	Within groups	2666	316	8.44		
	Total	2764	319			
Availability	Between groups	20	3	6.75	3.14	0.026
	Within groups	678	316	2.15		
	Total	699	319			
Demand	Between groups	24	3	7.92	4.70	0.003
	Within groups	533	316	1.69		
	Total	557	319			
Understanding	Between groups	16	3	5.27	2.72	0.045
	Within groups	612	316	1.94		
	Total	628	319			

Table 6
Means and Standard Deviation of team member *SA* per condition (*N*=80).

	Enriched	Not Enriched
Centralized	(3.43, 2.78)	(4.73, 2.48)
Decentralized	(4.30,2.38)	(3.43, 2.49)

Table 7
Tukey HSD and Duncan post-hoc test for situation awareness.

	Setting	*N*	Subset for alpha=0.05	
			1	2
Tukey-HSD	DNE	80	3.425	
	CE	80	3.475	
	DE	80	4.300	4.300
	CNE	80		4.725
	Sig.		0.228	0.791
Duncan	DNE	80	3.425	
	CE	80	3.475	
	DE	80	4.300	4.300
	CNE	80		4.725
	Sig.		0.072	0.355

awareness at the $p < .05$ level, $F(3,316)=3.86$, $p=0.01$, as well as on availability ($F(3,316)=3.14$, $p=0.026$), demand ($F(3,316)=4.70$, $p=0.003$), and understanding ($F(3,316)=2.72$, $p=0.045$). Table 6 summarizes the means and standard deviations of the situation awareness in the four conditions.

Post-hoc comparisons using the Tukey Honest Significant Difference (HSD) and Duncan test, as shown in Table 7, indicate that the mean scores for *SA* in the Centralized Not Enriched (CNE) condition ($M=4.73$, SD=2.48) are significantly higher than the mean scores for *SA* in the conditions Centralized Enriched (CE) ($M=3.48$, SD=2.92) and Decentralized Not Enriched (DNE) ($M=3.43$, SD=2.49). However, *SA* in the Decentralized Enriched (DE) condition ($M=4.30$, SD=2.38) is not significantly different from *SA* in any of the other conditions: neither the CNE nor the enriched conditions CE and DNE lead to significant differences.

The situation awareness for team members working with *enriched information* is not statistically significantly different in the centralized and decentralized condition (CE and DE, respectively); in case of non-enriched information there is a statistically significant difference between centralized (CNE) and decentralized (DNE) conditions, with team members in the CNE condition attaining higher situation awareness. The situation awareness for team members working in *centralized conditions* is statistically significantly better for non-enriched information (CNE) than for enriched information (CE); for decentralized conditions there is no statistically significant difference. Remarkably, the team members' situation awareness is not statistically significantly different between the centralized enriched (CE) and decentralized non-enriched (DNE), and between the decentralized enriched (DE) and centralized non-enriched (CNE) conditions. These findings are visualized in Fig. 1, with solid lines between conditions indicating statistical significance, gray lines non-significance. Double-sided arrow lines and the symbol NS indicates non-significant difference between conditions, while the direction of the single arrow line and the symbol '$<$' point towards the condition with the lower SA.

As such, we can conclude that Hypothesis 1 **is not supported**: team members do not attain significantly different situation awareness in the enriched conditions as compared to the non-enriched conditions: situation awareness in the CE condition is actually worse than in the CNE condition, and situation awareness in the DE and DNE conditions is not statistically significantly different. Hypothesis 2 **is partially supported**: team members attain higher situation awareness in centralized conditions as compared to decentralized conditions for non-enriched information only (CNE and DNE). Finally, we have not found a significant positive interaction effect: the situation awareness of the team members working with enriched information in the centralized CE condition is not statistically significantly different from the DNE condition. In other words, Hypothesis 3 **cannot be supported**.

As the ANOVA results in Table 6 show significant differences for of demand *D*, availability *A* and understanding *U*, we have examined these dimensions in more detail and conducted post-hoc tests for these dimensions (see Appendix A). Overall, the results from the post-hoc tests for demand, availability and understanding provide the following insights: for team members working *in the enriched conditions*, the results show that in centralized conditions (CE) they have a significantly lower understanding than in the decentralized condition DE (with a low level of significance, however). Yet, there is no significantly different demand and availability, which is not sufficient to lead to significantly different situation awareness among the CE and DE conditions. Team members working in the *non-enriched conditions* have a higher availability, lower demand and higher understanding in centralized conditions (CNE) as compared to team members working in decentralized conditions (DNE), confirming the higher situation awareness in the CNE condition compared to the DNE condition. *In the centralized conditions*, team members working with enriched information (CE) experience a significantly higher demand, lower availability and a worse understanding than working with non-enriched information (CNE), confirming the worse situation awareness in the CE condition compared to the CNE condition. In decentralized conditions, only the availability of the team members is significantly different, with a lower availability when working with non-enriched information (DNE), which is not sufficient to lead to significantly different situation awareness among the conditions DNE and DE. Finally, the CE and DNE conditions are statistically significant different only for availability, which is not sufficient to lead to significantly different situation awareness among these conditions.

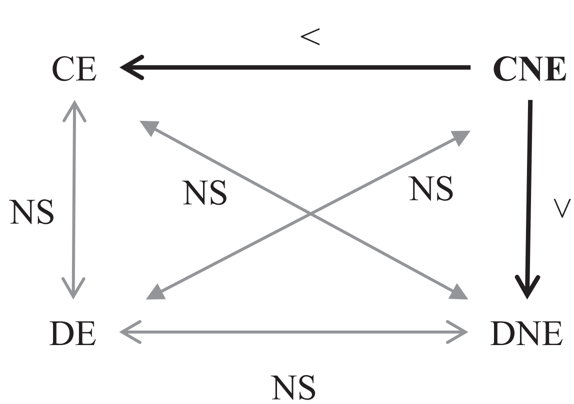

Fig. 1. Schematic overview of the findings for situation awareness.

6.2. Situation awareness of the coordinators

Given their special role in the team, we focus in this section on the coordinators. A one-way ANOVA was conducted to compare the effect of enriching and centralizing information on the coordinator's situation awareness as well as the underlying dimensions. Note that we have 4 coordinators per condition, each having 5 measures of *SA*. The results are shown in Table 8.

The ANOVA shows that there is a statistically significant effect of information enrichment and centralization on the coordinators' situation awareness at the $p<.05$ level, $F(3,76)=7$, $p=0.001$, as well as on availability ($F(3,76)=4$, $p=0.019$), demand ($F(3,76)=7$, $p<0.001$), and understanding ($F(3,76)=8$, $p<0.001$). Table 9 summarizes the means and standard deviations of the coordinators' situation awareness in the four conditions.

As for the team members, we conduct Tukey HSD and Duncan post-hoc tests on the coordinators' situation awareness, demand, availability and understanding. In contrast to the findings for the team members, however, both tests give slightly different results, which can be explained by the characteristics of the tests: the Duncan test is more permissive, i.e., identifies significant differences that are not made in Tukey's test.

Table 8
Anova analysis of SA and its dimensions for the coordinators.

		Sum of squares	*df*	Mean square	*F*	Sig.
Situation awareness	Between groups	178	3	59	7	0.001
	Within groups	691	76	9		
	Total	869	79			
Availability	Between groups	33	3	11	4	0.019
	Within groups	242	76	3		
	Total	275	79			
Demand	Between groups	22	3	7	7	0.000
	Within groups	77	76	1		
	Total	100	79			
Understanding	Between groups	43	3	14	8	0.000
	Within groups	140	76	2		
	Total	182	79			

Table 9
Means and standard deviation of situation awareness for coordinators ($N=20$).

	Enriched	Not enriched
Centralized	(0.7, 3.71)	(3.7,3.26)
Decentralized	(4.65,2.43)	(2.3,2.45)

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Table 10 shows that both tests agree that the coordinators' mean scores for *SA* in the CE condition (*M*=0.7, SD=3.71) are significantly different from, and lower than, the mean scores for *SA* in the conditions CNE (*M*=3.7, SD=3.26) and DE (*M*=4.65, SD=2.43). The mean scores for *SA* in the CE condition are, however, not significantly different from the mean scores for *SA* in the DNE condition (*M*=2.3, SD=2.45). The Duncan test moreover indicates that the coordinators' mean scores for *SA* in the CNE condition are significantly lower than the mean scores for *SA* in the DE condition (*M*=4.65, SD=2.43), yet this result is not confirmed in the more restrictive Tukey test. Both tests however agree that the coordinators' mean scores for *SA* in the non-enriched conditions CNE and DNE are not significantly different.

The situation awareness for coordinators working with *enriched information* is statistically significantly worse in the centralized condition (CE) than in the decentralized condition (DE); in case of *non-enriched information* there is no statistically significant difference between centralized (CNE) and decentralized (DNE) conditions. The situation awareness for coordinators working *in centralized conditions* is statistically significantly worse for enriched information (CE) than for non-enriched information (CNE); for *decentralized conditions* there is no statistically significant difference between enriched (DE) and non-enriched information (DNE). The coordinators' situation awareness in the centralized enriched (CE) and decentralized non-enriched (DNE) conditions, or in the DE and CNE conditions, are not statistically significantly different. These findings are visualized in Fig. 2, where the same graphic conventions apply as in Fig. 1.

As such, we can conclude that Hypothesis 4 **is not supported**: coordinators do not attain significantly better situation awareness in the enriched conditions as compared to the non-enriched conditions: situation awareness in the CE condition is worse than in the CNE condition and situation awareness in the DE and DNE conditions is not statistically significantly different. Hypothesis 5 **is partially supported**: coordinators do attain lower situation awareness in centralized conditions as compared to decentralized conditions for enriched information only; there is no significant difference for non-enriched information. Finally, there seems to be no significant positive interaction effect for coordinators working with enriched information in the centralized CE condition: the coordinators' situation awareness in this condition is not statistically significantly different from their situation awareness in the DNE condition. In other words, Hypothesis 6 **is supported**.

Table 10
Tukey HSD and Duncan post-hoc test for situation awareness for coordinators.

	Setting	*N*	Subset for alpha=0.05		
			1	2	3
Tukey-HSD	CE	20	0.7		
	DNE	20	2.3	2.3	
	CNE	20		3.7	
	DE	20		4.65	
	Sig.		0.342	0.074	
Duncan	CE	20	0.7		
	DNE	20	2.3	2.3	
	CNE	20		3.7	3.7
	DE	20			4.65
	Sig.		0.097	0.146	0.322

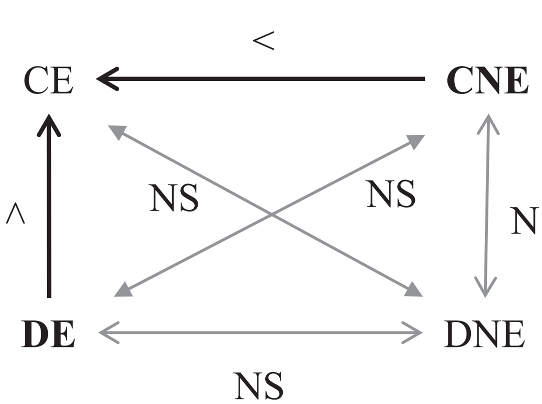

Fig. 2. Schematic overview of the findings for situation awareness for the coordinators.

As in the analysis for the team members, we also have conducted post-hoc tests on the underlying dimensions of demand, availability and understanding, as shown in Appendix B. The results for the post-hoc tests for demand, availability and understanding for coordinators show that in the CE condition demand is significantly higher and availability and understanding are significantly lower than in the DE condition, explaining the worse situation awareness. The non-enriched conditions CNE and DNE are only significantly different with respect to understanding, which is not sufficient to lead to significantly different situation awareness. In the centralized conditions, coordinators working with enriched information (CE) experience a significantly higher demand and lower understanding than working with non-enriched information (CNE), confirming the worse situation awareness in the CE condition compared to the CNE condition. In decentralized conditions, only the understanding of the coordinators is significantly different, with a lower understanding when working with non-enriched information (DNE), which is not sufficient to lead to significantly different situation awareness among the conditions DNE and DE. The CE and DNE conditions are statistically significant different only for demand, which is not sufficient to lead to significantly different situation awareness among these conditions.

These findings reveal an important difference: while for the team members only CNE leads to higher situation awareness than CE and DNE, we find that for the coordinators both CNE and DE lead to higher situation awareness than CE. This highlights the specific demands for the coordinators who need to have a broader overview of the situation than the individual team members in order to distribute information, allocate resources, and assign tasks. Other than expected and hypothesized, enriched information leads to relatively high demand, and does thus not help improve the situational awareness of the coordinators in the centralized setting.

6.3. Situation awareness of the observers

Finally, we also analyze how the observers' rate the situation awareness of the teams. The descriptive statistics for the observers' perceived *SA*, *D*, *A* and *U* are provided in Table 11. A one-way ANOVA was conducted to compare the difference between the situation awareness assessments of the observers and the team members, as well as the effect of enriching and centralizing information on the situation awareness (and the underlying dimensions) in the teams as perceived by the observers in the different conditions. Recall that we have 2 observers per team, for each of the 4 teams per condition, each having 5 measures of *SA*.

Considering first the differences between the different groups of participants, Table 12 provides the results of a one-way ANOVA test performed for team members and observers (*N*=120). The results show highly significant differences between the groups.

A Tukey HSD Test (see Table 13) shows that while the situational awareness is in general rated lower by the observers, we

Table 11
Descriptive statistics of *SA* and its dimensions as rated by observers ($N=40$).

Mean *SA*	SD *SA*	Mean *D*	SD *D*	Mean *A*	SD *A*	Mean *U*	SD *U*
DNE							
1.55	3.45	5.45	1.04	3.65	1.51	3.35	1.51
CNE							
3.50	4.25	4.25	1.72	4.60	1.87	3.15	1.44
CE							
3.18	3.97	5.20	1.34	3.95	1.66	4.42	1.53
DE							
2.35	3.33	5.42	1.13	4.08	1.56	3.35	1.51

Table 12
ANOVA analysis of SA and its dimensions across all groups.

		Sum of squares	*df*	Mean square	*F*	Sig.
Situation awareness	Between groups	388.054	4	97.014	9.456	0
	Within groups	4873.344	475	10.26		
	Total	5261.398	479			
Understanding	Between groups	102.254	4	25.564	11.92	0
	Within groups	1018.644	475	2.145		
	Total	1120.898	479			
Demand	Between groups	73.635	4	18.409	10.942	0
	Within groups	799.156	475	1.682		
	Total	872.792	479			
Availability	Between groups	70.469	4	17.617	7.574	0
	Within groups	1104.831	475	2.326		
	Total	1175.3	479			

only find significant differences ($p<0.05$) between observers and fire (mean difference -2.193) and medical (mean difference -1.919) team members. Thus, Hypothesis H7 **is partially supported**.

To analyze the impact of the treatments on the situation awareness ratings of the observers, we performed an additional ANOVA test, only for the observers. The ANOVA results as shown in Table 14 indicate that there is no statistically significant effect of information enrichment and centralization on the observers' rating of the team situation awareness, nor is there on the availability rating. There is a statistically significant effect on their ratings for demand ($F(3,156)=7.188$, $p<0.001$) and understanding ($F(3,156)=5.156$, $p=0.002$). Table 15 summarizes the means and standard deviations of the observers' ratings in the four conditions.

The ANOVA results show that the observers' ratings of the team's *SA* and *A* are not significantly different among the conditions, yet the ratings for the teams' *D* and *U* are significantly different. We have also conducted Tukey HSD and Duncan post-hoc tests for dimensions *D* and *U* for the observers, as shown in Appendix C. We find that the observers rate the teams' demand in the CNE condition to be significantly lower than in any other condition. This corresponds to what the team members actually experienced (see Table A1 in Appendix A). However, the observers consider the teams' understanding in the CE to be significantly higher than in the non-enriched CNE and DNE conditions, and not significantly different from the DE condition. This is in stark contrast with the team members' experiences, as their understanding in the CE condition is not significantly different from their understanding in the non-enriched CNE and DNE conditions, and significantly lower than in the DE condition (see Table A3 in Appendix A). This finding confirms previous work conducted in different contexts (Matthews et al., 2011; Salmon et al., 2006) that shows that the ratings of observers are typically not in line with the team members assessments, particularly not in situations of stress and time pressure.

7. Emergency response management information systems design implications

Emergency response teams confronted with a fast-burning crisis need appropriate support to make sense of what is going on and to deal with problems of uncertainty, ambiguity and equivocality. Information systems can filter out information by focusing on specific cues to prevent information overload; provide access to contextual information; and support rapid information sharing. Our findings here show however that information processing and sharing may not necessarily lead to the desired outcome of better situation awareness.

Turoff et al. (2004) carefully examined the system design requirements for a Dynamic Emergency Response Management Information System (DERMIS), an information system designed to support the response to crises. The DERMIS design premises refer to the acute response phase and illustrate the support IS can provide to the teams actively involved in the response to a crisis. Three DERMIS design premises are of particular relevance here and listed in Table 16 below: information focus, free exchange of information and coordination.

In this paper, we have investigated the effect of enriching information (as a means to improve the information focus) and sharing information via a coordinator in the team (centralization) versus free exchange of information. Our findings indicate that the three design premises in Table 16 are affected in different ways by these interventions.

First, we have found that enriched and non-enriched information conditions are significantly different only if information is centralized. Indeed, our results show that in the centralized condition, the team members attain significantly *lower* situation awareness if information is enriched. This can be explained by the high demands on the coordinators in the centralized settings, whose resulting lower situation awareness seems to impact all team members. In other words, in a DERMIS where information is designed to be centralized, an enrichment of information negatively impacts situation awareness of the response teams. As a design premise, we can therefore state that *for a DERMIS where information is centralized, information should be non-enriched to avoid lower team situation awareness.*

Second, we have also found that the difference between centralized (via coordinator) and de-centralized (free exchange) information sharing is only significant if information is *not* enriched. In that case, teams in a centralized condition attain *higher* situation awareness. If information *is* enriched, centralized and de-centralized conditions are found to be not significantly different. As a design premise, we can therefore state that *for a DERMIS where information is non-enriched, information should be centralized in order to achieve higher team situation awareness.*

Our results also clarified design principles to support the role of coordinators. Overall, two conditions lead to higher situation awareness for them: centralization of non-enriched information (CNE) and enrichment of de-centralized information (DE); the

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Table 13
Tukey HSD for situational awareness across groups.

Dependent variable	(*I*) Setting	(*J*) Setting	Mean difference (*I*−*J*)	Std. error	Sig.	95% Confidence interval	
						Lower bound	Upper bound
SA	Coord.	Fire	−2.0000*	0.5065	0.001	−3.387	−0.613
		Police	−0.85	0.5065	0.448	−2.237	0.537
		Medical	−1.7250*	0.5065	0.006	−3.112	−0.338
		Observer	0.1938	0.4386	0.992	−1.007	1.395
	Fire	**Coord.**	**2.0000***	0.5065	0.001	0.613	3.387
		Police	1.15	0.5065	0.156	−0.237	2.537
		Medical	0.275	0.5065	0.983	−1.112	1.662
		Observer	2.1938*	0.4386	0	0.993	3.395
	Police	Coord.	0.85	0.5065	0.448	−0.537	2.237
		Fire	−1.15	0.5065	0.156	−2.537	0.237
		Medical	−0.875	0.5065	0.418	−2.262	0.512
		Observer	1.0438	0.4386	0.123	−0.157	2.245
	Medical	**Coord.**	**1.7250***	0.5065	0.006	0.338	3.112
		Fire	−0.275	0.5065	0.983	−1.662	1.112
		Police	0.875	0.5065	0.418	−0.512	2.262
		Observer	1.9188*	0.4386	0	0.718	3.12
	Observer	Coord.	−0.1938	0.4386	0.992	−1.395	1.007
		Fire	−**2.1938***	0.4386	0	−3.395	−0.993
		Police	−1.0438	0.4386	0.123	−2.245	0.157
		Medical	−**1.9188***	0.4386	0	−3.12	−0.718

* indicates the difference in means is statistically significant at the .05 level.

Table 14
Anova analysis of SA ratings and its dimensions for the observers ($N=40$).

		Sum of squares	***df***	**Mean square**	***F***	**Sig.**
Situation Awareness	Between groups	91.919	3	30.64	2.158	0.095
	Within groups	2214.775	156	14.197		
	Total	2306.694	159			
Availability	Between groups	18.869	3	6.29	2.296	0.08
	Within groups	427.375	156	2.74		
	Total	446.244	159			
Demand	Between groups	38.369	3	12.79	7.188	0
	Within groups	277.575	156	1.779		
	Total	315.944	159			
Understanding	Between groups	37.719	3	12.573	5.156	0.002
	Within groups	380.375	156	2.438		
	Total	418.094	159			

Table 15
Average and standard deviation of situation awareness as rated by the observers ($N=40$).

	Centralized	Decentralized
Not enriched	(3.50, 4.25)	(1.55, 3.45)
Enriched	(3.18, 3.17)	(2.35, 3.33)

former condition allows for more control and interpretation by the coordinator, while the latter condition essentially requires and enables the team members to collaborate. Which of both conditions most improves coordination depends on the character of the crisis: if engagement and cooperation across team members are important, or if there are many organizations involved (leading to a higher workload for the coordinator), DE seems to be the best option to respond to fast-burning crises; CNE seems to be favorable if very fast action is required that can be performed rather independently by the individual team members. As design premises, we can therefore state that *(i) for a DERMIS where information is centralized, information should be non-enriched to lead to higher situation awareness for coordinators; (ii) for a DERMIS where information is not centralized, information should be enriched to lead to higher situation awareness for coordinators.*

We also find that the default response setting of non-enriched and non-centralized information (DNE) appears to limit coordination neglect, yet has the worst overall attainment of situation awareness for the team members.

8. Conclusions

In this paper, we have experimentally investigated two possible ways of improving situation awareness in teams responding to a fast-burning crisis: providing enriched information, and centralizing information sharing via a coordinator in the team. We conducted experiments with professional crisis responders who were tasked to respond to two realistic cases of a fast-burning crisis. In a 2×2 design, we contrasted conditions of (non-)enriched information with conditions of (de-)centralized information sharing. Throughout the experiment, we measured the situation awareness of the team members at fixed time intervals using the SART technique. In addition, two observers per team provided an external rating of the team's situational awareness using the same technique.

The statistical analyses of our experiment enable us to unravel the very different roles of centralized and enriched information on the teams' situation awareness. Remarkably, we find that the difference between centralized and de-centralized information sharing is only significant if information is *not* enriched, and that enriched and non-enriched information conditions are significantly different only if information is centralized. The conditions of centralization of non-enriched information (CNE) and enrichment of de-centralized information (DE) were found to lead to higher situation awareness for the coordinators. Finally, we also find evidence that external ratings of situation awareness by

Table 16
Three DERMIS design premises.

DERMIS design premise	Description
Information focus	Those who are dealing with a crisis are flooded by information. Therefore, the support system should carefully filter information that is directed towards actors. However, they must still be able to access all (contextual) information related to the crisis as the information elements, which are filtered out by the system, may still be of vital importance.
Free exchange of information	During crisis response, it is important that a great amount of information can be exchanged among stakeholders so that they can delegate authority and conduct oversight. This, however, induces a risk of information overload, which, in turn, can be a risk to the crisis response effort. The response system should somehow protect participants from information overload.
Coordination	Due to the unpredictable nature of a crisis, the exact actions and responsibilities of individuals and teams cannot be determined ex ante. Therefore, the system should be able to support the flow of authority directed towards where the action takes place (usually on a low hierarchical level), but also the reverse flow of accountability and status information upward and sideways through the organization.

observers should be treated with care: the observers' ratings are in stark contrast with the ratings from the teams themselves, in the different conditions. This confirms earlier findings on the gap between external and internal ratings of situation awareness.

In conclusion, our findings show that a delicate balance needs to be found between information richness and information centralization, and this for the different roles in the teams. Additional research is needed to further analyze the intricacies involved, under different conditions of information supply, time pressure and complexity.

Acknowledgments

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Appendix A. Post-hoc tests on the underlying dimensions of demand, availability and understanding for the team members

Post-hoc comparisons for the demand *D* using the Tukey HSD and Duncan test, as shown in Table A1, indicate that the mean scores for *D* in the CNE condition ($M=4.65$, $SD=1.25$) are significantly different from, and *lower* than, the mean scores for *D* in the conditions DNE ($M=5.21$, $SD=1.1$), CE ($M=5.26$, $SD=0.99$) and DE ($M=5.34$, $SD=1.17$).

Post-hoc comparisons for the availability *A* using the Tukey HSD and Duncan test, as shown in Table A2, indicate that the mean scores for *A* in the CNE condition ($M=4.89$, $SD=1.17$) are significantly *higher* than the mean scores for *A* in the DNE ($M=4.25$, $SD=1.64$) condition. The availability *A* in the centralized conditions CE ($M=4.49$, $SD=1.41$) and DE ($M=4.79$, $SD=1.05$) is not significantly different, nor is there a significant difference with the availability in the non-enriched conditions CNE and DNE.

Post-hoc comparisons for the understanding *U* using the Tukey HSD and Duncan test, as shown in Table A3, indicate that the mean scores for *U* in the DE condition ($M=4.85$, $SD=1.12$) are significantly *higher* than the mean scores for *U* in the CE ($M=4.25$, $SD=1.53$) condition. The understanding *U* in the not-enriched conditions DNE ($M=4.39$, $SD=1.21$) and CNE ($M=4.89$, $SD=1.33$) is not significantly different, nor is there a significant difference with the understanding in the enriched conditions CE and DE.

Table A1
Tukey HSD and Duncan post-hoc test for demand *D*.

	Setting	*N*	Subset for alpha=0.05	
			1	2
Tukey-HSD	CNE	80	4.65	
	DNE	80		5.21
	CE	80		5.26
	DE	80		5.34
	Sig.		1	0.929
Duncan	CNE	80	4.65	
	DNE	80		5.21
	CE	80		5.26
	DE	80		5.34
	Sig.		1	0.57

Table A2
Tukey HSD and Duncan post-hoc test for availability *A*.

	Setting	N	Subset for alpha=0.05	
			1	2
Tukey-HSD	DNE	80	4.25	
	CE	80	4.49	4.49
	DE	80	4.79	4.79
	CNE	80		4.89
	Sig.		0.096	0.312
Duncan	DNE	80	4.25	
	CE	80	4.49	4.49
	DE	80		4.79
	CNE	80		4.89
	Sig.		0.306	0.104

Table A3
Tukey HSD and Duncan post-hoc test for understanding *U*.

	Setting	*N*	Subset for alpha=0.05	
			1	2
Tukey-HSD	CE	80	4.25	
	DNE	80	4.39	4.39
	CNE	80	4.49	4.49
	DE	80		4.85
	Sig.		0.703	0.155
Duncan	CE	80	4.25	
	DNE	80	4.39	
	CNE	80	4.49	4.49
	DE	80		4.85
	Sig.		0.313	0.101

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Appendix B. Post-hoc tests on the underlying dimensions of demand, availability and understanding for the coordinators

Table B1 shows that both tests agree that the coordinators' mean scores for *D* in the CE condition (*M*=6.75, SD=0.44) are significantly higher than the mean scores for *D* in the non-enriched conditions CNE (*M*=4.65, SD=1.25) and DNE (*M*=5.21, SD=1.10). The coordinators' mean scores for *D* in the enriched conditions (CE and DE) are not significantly different according to the Tukey test. The Duncan test, however, does find that the coordinators' mean scores for *D* in the CE condition are significantly higher than the mean scores for *D* in the DE condition (*M*=5.34, SD=1.17).

Table B1
Tukey HSD and Duncan post-hoc test for demand *D* for coordinators.

	Setting	*H*	Subset for alpha=0.05	
			1	2
Tukey-HSD	DNE	20	5.35	
	CNE	20	5.6	
	DE	20	6	6
	CE	20		6.75
	Sig.		0.182	0.095
Duncan	DNE	20	5.35	
	CNE	20	5.6	
	DE	20	6	
	CE	20		6.75
	Sig.		0.056	1

Table B2 shows that both tests agree that the coordinators' mean scores for *A* in the centralized enriched CE condition (*M*=4.49, SD=1.41) are significantly lower than the mean scores for *A* in the decentralized enriched condition DE (*M*=4.79, SD=1.05). The coordinators' mean scores for *A* in the non-centralized conditions are not significantly different. The Duncan test finds that the coordinators' mean scores for *A* in the DE condition are significantly different from, and higher than, the mean scores for *A* in the CNE condition (*M*=4.89, SD=1.17) – that result is however not confirmed in the Tukey test.

Table B2
Tukey HSD and Duncan post-hoc test for availability *A* for coordinators.

	Setting	*H*	Subset for alpha=0.05	
			1	2
Tukey-HSD	CE	20	3.75	
	DNE	20	3.8	
	CNE	20	4.15	4.15
	DE	20		5.35
	Sig.		0.893	0.154
Duncan	CE	20	3.75	
	DNE	20	3.8	
	CNE	20	4.15	
	DE	20		5.35
	Sig.		0.509	1

Table B3 shows that both tests agree on all results. The coordinators' mean scores for *U* in the centralized enriched CE condition (*M*=4.25, SD=1.53) are significantly lower than the mean scores for *U* in the decentralized enriched condition DE (*M*=4.85, SD=1.12). Conversely, the coordinators' mean scores for *U* in the centralized non-enriched CNE condition (*M*=4.89, SD=1.33) are significantly different from, and higher than, the mean scores for *U* in the decentralized non-enriched condition DNE (*M*=4.39, SD=1.21). The coordinators' mean scores for *U* in the CE and DNE, and CNE and DE, conditions are not significantly different.

Table B3
Tukey HSD and Duncan post-hoc test for understanding *U* for coordinators.

	Setting	*N*	Subset for alpha=0.05	
			1	2
Tukey-HSD	CE	20	3.7	
	DNE	20	3.85	
	CNE	20		5.15
	DE	20		5.3
	Sig.		0.985	0.985
Duncan	CE	20	3.7	
	DNE	20	3.85	
	CNE	20		5.15
	DE	20		5.3
	Sig.		0.727	0.727

Appendix C. Post-hoc tests on the underlying dimensions of demand and understanding for the observers

Post-hoc comparisons for the demand *D* using the Tukey HSD and Duncan test, as shown in Table C1, indicate that the mean scores for *D* in the CNE condition (*M*=4.25, SD=1.72) are significantly lower than the mean scores for *D* in the DNE (*M*=5.45, SD=1.04), CE (*M*=5.20, SD=1.34) and DE (*M*=5.42, SD=1.13) conditions.

Table C2 shows that both tests agree that the observers' mean scores for the teams' understanding *U* in the centralized enriched CE condition (*M*=4.42, SD=1.53) are significantly higher than the mean scores for *U* in the centralized and decentralized non-enriched condition CNE (*M*=3.15, SD=1.44) and DNE (*M*=3.35, SD=1.51). The observers' mean scores for *U* in the non-enriched conditions are not significantly different. The Duncan test finds that the observers' mean scores for *U* in the CE condition are significantly different from, and higher than, the mean scores for *U* in the DE condition (*M*=3.35, SD=1.51) – that result is however not confirmed in the Tukey test.

Table C1
Tukey HSD and Duncan post-hoc test for demand *D* as rated by the observers.

	Setting	*N*	Subset for alpha=0.05	
			1	2
Tukey-HSD[a]	CNE	40	4.25	
	DE	40		5.2
	CE	40		5.43
	DNE	40		5.45
	Sig.		1	0.836
Duncan[a]	CNE	40	4.25	
	DE	40		5.2
	CE	40		5.43
	DNE	40		5.45
	Sig.		1	0.434

[a] Uses Harmonic Mean Sample Size = 80.

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Table C2
Tukey HSD and Duncan post-hoc test for understanding *U* as rated by the observers.

	Setting	*N*	Subset for alpha=0.05	
			1	2
Tukey-HSD[a]	CNE	40	3.15	
	DNE	40	3.35	
	DE	40	3.7	3.7
	CE	40		4.43
	Sig.		0.396	0.165
Duncan[a]	CNE	40	3.15	
	DNE	40	3.35	
	DE	40	3.7	
	CE	40		4.43
	Sig.		0.139	1

[a] Uses Harmonic Mean Sample Size = 80.

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