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Psychophysiology, task complexity, and team factors determine emergency response teams' shared beliefs

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ABSTRACT

In field settings where the objective truth is not known, the extent to which you have the same understanding of the situation as your team leader may be used as an indicator for a team's situation awareness. Two experiments showed emergency response team members' degree of shared beliefs (measured as a 'similarity index') to be associated with which team they are in, but not with which position they have in the team. This indicates that factors specific to the teams, e.g. the leader's behavior, the team's shared experience, or communication patterns, are important for a team's situation awareness. In the second experiment, task complexity was manipulated with a scripted scenario design and heart rate variability was measured as an indicator of executive function. Shared beliefs were shown to be associated with the degree of high frequency modulation of heart rate variability. Further, shared beliefs were associated with the designed task complexity for some teams. The experiments showed no association between the measure of shared beliefs and subjective reports of situation awareness.

1. Introduction

1.1. Mental representations in safety team-work

Safety critical work and work in high reliability organizations is often done in teams, where two or more operators with different responsibilities and skill sets cooperate toward shared goals (Salas et al., 1992). The organization of operators into teams may be due to workload demands or due to requirements for diverse skill sets. There may be advantages to performing safety critical work in teams compared to doing it as individual work, as the different team members can monitor and assist each other to achieve higher reliability. However, organizing the work in teams also carries disadvantages, such as creating a more complex work environment, losing resources to imperfect communication and coordination, and the risk for uncoordinated team members working toward opposing goals.

In order for team organization and team training to reduce adverse team effects, there is a need for research on the factors that influence a team's efficiency and safe functioning. Relationships suggested by a-priory theorizing or correlational findings (e.g. Eid et al., 2011; Gross and Kluge, 2012; Guldenmund, 2000; Kanno et al., 2013) should be tested in experimental designs. In order to ensure the applied value of the research, studies should strive for both ecological validity and controlled hypothesis testing.

A fundamental assumption when studying team reliability is that individual and aggregated task performance improves when the team members have accurate mental representations of the situation. Further, a team where all the members have accurate representations will also have similar (or shared) representations. This should facilitate communication and cooperation, and thus increase the team's overall performance (Cannon-Bowers and Salas, 2001; Mathieu et al., 2000; Sætrevik and Eid, 2014; Salas et al., 2008; Saner et al., 2009).

A number of theoretical concepts and measurement approaches have been suggested to describe the accuracy and cohesion of team's mental representations. *Mental models* are organized and dynamic internal representations of past experiences (Glaser, 1989), and individual team members will have mental models describing their tasks and the team's work. The mental models could to some extent be similar between individual members of a team, indicating that they have the same knowledge or assumptions about the situation. Salas and colleagues (Cannon-Bowers et al., 1993; Salas et al., 1992) have referred to this phenomenon as a team having *shared mental models* (SMM). The content of the SMMs may be task-related (e.g. relating to the equipment or job strategies) or team-related (information about e.g. interaction patterns in the team, or the skills of various team members, Mathieu

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et al., 2000). Salas et al. (2007) argued that a higher degree of SMM is indicated by a team using closed-loop communication, performance monitoring between team members, and displaying supportive behavior.

The term *situation awareness* (SA) refers to the extent to which an individual's mental representation of the dynamic environment corresponds to the actual environment. SA also refers to the process that creates this representation in an interaction with the environment. The prevailing model for SA divides the concept into three hierarchical levels, which consist of perceiving, understanding, and predicting the environment (Endsley, 1988a, 1995). To account for SA in teams, the concept *team SA* has been introduced to describe the aggregation of individual team members' accurate mental representations of their own fields of responsibility, while *shared SA* has been introduced to describe the degree to which all team members have accurate mental representations of issues that are relevant for the whole team (Endsley, 1995). This classification emphasizes that some information in a team's work needs to be shared, while other information does not.

1.2. Relevance of mental representation accuracy for emergency response team-work

To organize work into teams may have effects that are adverse for safety, for example that the team members misunderstand instructions, work toward opposing goals, fail to utilize all the team's information or resources, get involved in interpersonal conflicts or social loafing. For a high reliability organization such as the emergency response teams (ERT) of offshore hydrocarbon energy industry, well-coordinated team-work is critical to mission success. The members of such teams may have other tasks and work teams in their day-to-day jobs, but have to muster to the ERT in case of emergencies. In some cases the emergency preparedness approach may be organized into a first-line (or frontline) operational ERT, a second-line tactical ERT, and a third-line strategic ERT. While the first-line ERT directly interacts with the event causing the emergency, the second-line ERT is tasked with collecting and organizing all information relevant for the event, relaying information between parties involved in the event, planning for future development of the event, and advising the first-line ERT.

Everyday safety (e.g. avoiding mistakes, errors and slips during normal operation, Reason, 1990) may be determined by other factors than those important for maintaining safety while dealing with an emergency. The task-work involved for an ERT trying to normalize an emergency is done while team members are aware of the high stakes involved, their physiological activation may be increased, the teams may have limited experience in their emergency tasks and with working together, and the task to be solved may be novel. Thus an ERT's work may be especially prone to erroneous actions due to inaccurate mental representations for individual team members or due to the team members having non-shared mental models. Further, the team-work errors may be more difficult to notice and the consequences of team-work errors may be larger than during normal operations.

1.3. Determinants for mental representation accuracy

One may propose three domains of determinants for the extent to which team members have accurate representations about their environment: the individual, the team and the task. Individual team members vary in their level of competency and skill (see Gross and Kluge, 2014, for an applied example), which may allow them different baselines for learning about and understanding their environment. Further, one may expect individual variation in affective and motivational aspects, which may be reflected in psychophysiological activation and the capacity for mental representation (Gonzalez, 2005; Gonzalez et al., 2005). To some extent, the organization may enhance such individual factors through personnel selection and training, and through influencing the cultural safety values. In a research design where team or task factors are examined (as in the one presented here), the contribution of individual factors would create noise in the analysis and would be averaged away. On the other hand, if the mental representations are predominantly determined by individual factors, the analyses would not find significant contributions when analyzing team or task factors.

In addition to team members developing mental representations through their individual information gathering and hypothesis testing, there is also sharing, discussion and organization of information between team members. This makes the team-level a relevant domain for determinants for mental representation accuracy. The concept of *team cognition* (Fiore and Salas, 2004; Salas et al., 2007) has been used to describe multi-level interactions and dependencies between intraindividual and interindividual processes. Team cognition is seen as analogous to individual cognition, and is an emergent state where important information is organized, represented and distributed, which allows anticipation and execution of the task (Kozlowski and Ilgen, 2006). Different traditions tend to measure team cognition either as compositional representation (i.e. shared SA or SMM) or as compilational representations (transactive memory systems). Salas et al. (2007) argued that SMM could be a reliable marker for team cognition, which would allow the team members to make accurate causal explanations and adapt efficiently to each other. Meta-analyses have indicated that team cognition has strong positive relationships to behavior, motivation and performance (DeChurch and Mesmer-Magnus, 2010; Mathieu et al., 2000, 2010). One may expect different teams to differ in their capacity for team cognition, which could cause differences in the accuracy of team members' representations and hence of the team's aggregated representations. It has been argued (DeChurch and Mesmer-Magnus, 2010) that factors such as team leadership, shared experience and training, and workplace design may enhance team cognition. A related concept is *macrocognition in teams*, which tends to emphasize collective knowledge building in novel situations (Fiore et al., 2010). This research tradition originated in naturalistic decision-making research, and parallels distributed cognition literature. The concepts of team cognition and macrocognition both correspond to the idea that an effective team works with a high degree of coordination due to team members having the same understanding of the situation and task goals.

A third domain of predictors for a team's accurate mental representations is aspects of the task the team is working on and how the team members are situated in the task (Gonzalez, 2005). A task may vary in its opaqueness, task complexity, and dynamic complexity (Diehl and Sterman, 1995; Hardman, 2009). As a task grows more complex it allows for more degrees of freedom in how the mental representations are structured (Wood, 1986), which increases the potential for inaccurate mental representation. Further, given that organizing work into teams always involves a specialization of tasks and competencies (as per the definition by Salas et al. (1992)), a team member holding a given position in the team will have a different access to and a different perspective on information about the task and the team's work than a team member in a different position. As revealed in the discussion of *team SA* and *shared SA* in Section 1.1, some information should be shared by team members in all positions, while some information can be exclusive to only some positions. If team members have different mental representations of the information that all positions should share, this can lead to reduced team performance and risk for human error. As for the information that is not shared in the team, a team member is likely to have more accurate