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A new model for understanding teamwork onboard: the shipmate model

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ABSTRACT

The increasing complexity onboard a ship underline the importance of crews that are able to coordinate and cooperate with each other to facilitate task objectives through a shared understanding of resources (e.g. team members' knowledge, skills and experience), the crew's goals, and the constrains under which they work. Rotation of personnel through 24/7 shift-work schedules and replacements often put crews in a position of having little or no previous history as a team. Findings from 3 studies indicated that unfamiliar teams used less efficient coordination strategies which reduced efficiency and increased levels of stress in situations where team members where experts on task, distributed or unknown to task and environment. Implications for staffing, safety and training are discussed.

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Key words: shared mental models, teamwork, distributed teamwork, adaptability

THE SHIPMATE MODEL

Teams are at the centre of how work gets done onboard a ship and are defined as 2 or more people carrying out highly interdependent tasks based on expertise distributed among team members with clearly assigned roles and responsibilities (e.g. bridge team; navigator, rudder and look out). Such teams work in a dynamic environment (e.g. in shore waters), share values and common goals (e.g. safe journey) and exist for a limited lifespan (e.g. a work shift [1]). Several investigations of disastrous maritime, aviation, military, medical and industrial accidents have found teamwork breakdowns (e.g. coordination, communication [2]). Hackman [3] concluded, however, that designing teams solely on the basis of members' expertise is no guarantee of success. In many cases, information management systems have been introduced to enhance team communication and information exchange. Stagl et al. [1] pointed out, however, that merely connecting experts with collaborate technology was not sufficient to guarantee effective performance (e.g., distributed teams; bridge and engine).

The working conditions onboard a ship represent a complex and dynamic environment; hence crews often face rapidly evolving and ambiguous situations where 1 correct solution is not always evident or possible. In addition, modern technologies increase the pressure through information overload and limiting time available to act. Salas et al. [4] stated that modern operational environments are characterised by a historically unparalleled accelerating rate of change that requires team flexibility, adaptability, and resilience. To cope, team members must integrate, synthesize, and share information, and they need to coordinate and cooperate to accomplish their mission as task demands change. Thus effective teams onboard must be able to do more than interact with tools, engines and systems etc. The increasing complexity onboard a ship underline the importance of crews that are able to coordinate and cooperate with each other to facilitate task objectives through a shared understanding of resources (e.g. members' knowledge, skills and experience), the crew's goals, and the constrains under which they work. In essence, crews onboard a ship face a dynamic, shifting and complex environment which rises a commensurate of task demands that members have to resolve through a coordinated process that combines their cognitive, motivational/affective and behavioural resources [5].

Hence, the rotation of personnel through 24/7 shift-work schedules and replacements make it difficult to maintain

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stable person/role expectations over time. Thus many crews consist of team members with little or no previous history as a team. This may influence both coordination and cooperation in teams and thereby efficiency. It is also reasonable to deduce that if unfamiliarity represent to much ambiguity and uncertainty then such constrains for team members may result in higher levels of stress related health issues. The international society meet the challenge of unfamiliarity with strict regulations where education, documentation, auditing, and certificates play an important role. But, it is questionable to claim that challenges with unfamiliarity are solved by international regulations alone. Do we still have a problem with unfamiliarity onboard?

Small group research has a long tradition of studying cognitive constructs such as group norms and role expectations that guide interpersonal interaction among team members [5]. Interpersonal interaction is important to team performance, for instance by influencing how willing we are to share information with other team members. In a knowledge-driven context, constructs that capture task-relevant interaction are of equal interest when performance and effectiveness are the subjects under investigation. Thus, familiarity is more than interpersonal relations and likes or dislikes. It is also about understanding other team members' behaviour while performing tasks. If you do not understand the behaviour (what or why) of a team member, then coordination (e.g. back-up behaviour) is difficult and your willingness to provide information is of less importance. Thus, it is surprising to discover that research on team cognition and task-related issues rarely is related to familiarity in Safety Critical Organisations (SCO). Mohammed et al. [6] stated in an overview of the field of team cognition that the role of "time together as a team" had been largely downplayed in past research on team cognition.

This is disturbing because the importance of team members having a shared understanding is underlined in dynamic situations that require high levels of flexibility and adaptability in the team [7, 8]. This indicates an important asset in teamwork, the transferability to novel situations, and a vital ability in SCO's, where procedures and routine are dominant, but where anomalies have the potential to result in severe consequences if not handled correctly. In their concept of Shared Mental Models (SMM), Cannon-Bowers et al. [7] suggest that more effective teams share similar mental models and understandings of the situation at hand.

SHARED MENTAL MODELS

Salas et al. [9] contend that SMM are a core aspect of the successful coordination of information and behaviour in expert teams. The construct of SMM is drawn from theories of individual mental models used to explicate individual cognitive functioning or understanding. At the individual level, mental models refer to a structure of known elements (e.g. declarative knowledge) and the relationship between those elements [10]. These structures serve as mechanisms that people use in order to describe the purpose and form of a system, as well as its functioning in its present and future state [11]. Cannon-Bowers and Salas [12] proposed extending the concept of individual mental models to the team performance domain, hypothesising that team performance is a function of the extent to which members held similarly organised expectations in relation to the task or each other. SMM are defined as a shared organised understanding and mental representation of key elements of the team's relevant environment. These SMM enable team members to form accurate explanations and expectations of the task. This will in turn enable team members to coordinate their actions and adapt their behaviour to the demands of the task and to other team members [7].

SMM are assumed to enable team members to predict task needs and the actions of other team members, and thus enable them to adapt their own behaviour accordingly without communicating explicitly. A number of studies have indicated that SMM contribute to increased team effectiveness [13–18].

SMM are based on the assumption that highly effective operational teams are able to understand the system at several levels. To make this possible, multiple shared models must be in action at the same time [7]. Rouse and Morris [11] proposed a taxonomy of mental models in which every level or type of model differed in importance depending on which task was to be solved. Some problems are solved through one type of mental model, while other problems are solved by integrating several mental models.

Cannon-Bowers et al. [7] proposed four types of SMM:

- Technology/equipment. To extract information, team members need to share an understanding and knowledge of how to control the technology and equipment with which they are interacting. This includes operating procedures, limitations and likely failures.
- Task at hand. It is also important that team members understand the task at hand and how to carry it out. This is shared knowledge about what information is important and how different types of information must be combined to give meaning. It is also important for the team members to understand the dynamics of the environment and how this impacts on their tasks (i.e. time constraints or uncertainty). This includes task procedures, task strategies, environmental constraints, likely contingencies, and scenarios.
- Team interaction. Each team member has to understand his/her own role in the overall task, what they as an individual team member contribute and how this is accomplished. This requires a common understanding

of who needs what and when in the team. This will enable the team members to understand when they must monitor other team members to support them with the proper behaviour or information, if required. This includes their roles/responsibilities, information sources, interaction patterns, communication channels, as well as role interdependencies.

— Team members. Team members must be familiar with the knowledge, skills, abilities, preferences, and other task-relevant attributes of their team-mates. It is proposed that their expectations of the behaviour of their team-mates will vary as a function of who makes up the team. And a SMM of team members enables team members to adjust their own behaviour to the other team members (e.g. 1 team member is on the verge of becoming overwhelmed by a high workload and other team members give support by taking on some of workload).

Espevik et al. [19–21] was particular interested in the last, SMM of team members and investigated whether familiarity influences coordination, resilience, and efficiency in high performance teams in safety-critical organisations.

First 24 active duty officers who made up four submarine attack teams (i.e. 6 team members each) where situated in two similar situations where they subsequently operated as intact teams and with one new, unfamiliar team member. The aim [19] was to investigate whether knowledge about individual team members would augment the effect of operational skills in predicting operational effectiveness in trained expert teams.

Secondly, based on a notion that some teams are physically separated (distributed) and have fewer opportunities to coordinate due to the absence of paralinguistic, non-verbal and other sensory cues, Espevik et al. [20] investigated if familiarity within teams could be hampered by physical separation between team members. Espevik et al. [20] situated familiar and less familiar cadets from the Royal Norwegian Naval Academy in simulator tasks [20]. Thus, the consequences for communication, physiological arousal, and efficiency in teams that are forced to coordinate their activities towards a shared goal in a distributed team setting were studied.

Thirdly, also with cadets from the Royal Norwegian Naval Academy in simulator tasks, Espevik et al. [21] followed the notion that expert teams also encounter novel situations, and the last question addressed was whether familiarity with other team member prepared teams for the unexpected (novel situations) or, to put it another way, whether they will learn more quickly.

The findings from these three studies [19–21] indicated that unfamiliar teams used less efficient coordination strategies. The coordination strategies used by unfamiliar expert teams was characterised by more overt and controlling communication (statements and orders per minute) during high workload [19], a lower global anticipation rate (i.e. less push of information [20]), and less adaptability(i.e. updates and priorities) and back-up statements (i.e. proving help, reducing workload for other team members) during novel situations [21]. In addition, unfamiliar teams showed less overt communication (e.g. confirmation) when confronted with a novel situation [20, 21]. Unfamiliar teams performed more poorly, being less accurate, quicker and achieving less mission success (i.e. more hits [19–21]). Unfamiliar teams were less physiologically aroused (heart rate) during low workload, and less during high workload, recovery, and decreasingly so during training [19–21].

Based on these 3 studies we propose a model, the shipmate model (Fig. 1) to explain the advantages of having SMM of team members.

THE SHIPMATE MODEL

Thus one way of understanding the findings is to look at what can happen when a team member becomes aware of a change in the environment (outer world). The other team members sense a change in his/her behaviour — "something has happened" — (e.g. the team member appears to be more concentrated, uncertain). This is in line with the proposed property of SMM that they enable the team to identify changes in the team and in team-mates [9]. This suggests that a SMM of team members enhances a team's sensitivity to change, enabling it to act accordingly (Fig. 1).

SENSITIVITY

The ability to detect deviancies, shortcomings, and uncertainty in members of the team was enhanced in familiar teams, and they focused on rectifying the situation. As a result, familiar teams put more effort into understanding and coping, even in situations where there was no immediate need for action (e.g. low workload). This, in turn, could result in an immediate increase in the observed heart rate during low workload [20] and a novel situation [21]. This could also help to explain why familiar teams performed better than unfamiliar during low workload [20]. Another argument in this connection is provided by the finding made when looking at heart rate during recovery, where only familiar teams decreased their heart rates [20, 21], indicating higher sensitivity and thereby adaptability of the organism to environmental demands [22].

Increased sensibility in familiar teams has at least 2 implications. First, the whole team implicitly shares within the team that a change has occurred, and they therefore become aware of changes more quickly and can cope with the reality of the change in the environment. Less irrelevant communication by the familiar teams [20] can be understood as better awareness and, consequently,

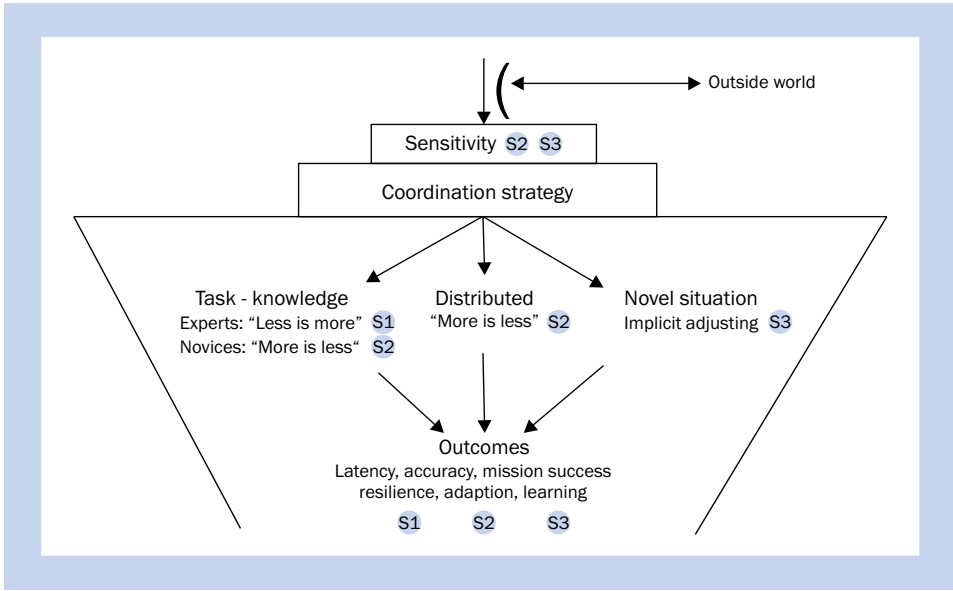

Figure 1. The shipmate model: The symbols S1/S2/S3 are understood as findings from Espevik et al. [19–21]. The logic is explained to be that when a change takes place in the outer world this is sensed (discovered) by one or 2 members in the team. Then the teams choose 3 different ways to coordinate based on what knowledge and skill they have on own task, if they are separated, or face a novel situation. This then give better outcomes (e.g. more hits)

a more appropriate strategy and an indication of a SMM of team members.

Second, familiar teams are able to adjust implicitly to the coordinating strategy that best fits the situation and the team. The second implication is in line with the theoretical framework for SMM, where Cannon-Bowers et al. [7] define the ability to implicitly anticipate what your team-mates need and, accordingly, what (i.e., information, action) they need from you. Thus, a SMM of team members enables the team to choose the coordination strategy that is best suited to coping with the situation and/or to the abilities of the team. These 3 studies indicate that the (implicit) choice of coordination strategy depends on 3 factors/questions: do we know the task, are we separated from other team members, and are we facing a novel situation (a learning situation)?

TASK KNOWLEDGE COORDINATION

If the team knows the task (are subject matter experts [19]) the coordination seems to be straightforward and in accordance with the original theoretical framework for SMM. The teams have a general SMM (of equipment, task, interaction, and team members) and are able to immediately start communicating implicitly. The appropriate coordination is "less is more", i.e., less communication (statements per minute) and less control (requests).

When facing a task they are not experts in [20], teams are forced to communicate more in order to learn the new elements in the task they as a team must adapt to. In such cases, familiar teams implicitly know that team-mates need more information and thus start to push it or display what Entin and Serfaty [23] call a higher global anticipation ratio to meet high workload. Thus, a SMM of team members enables them to choose a coordination strategy that can be characterised as "more is less", i.e. more transfer, task-oriented communication and monitoring (non-verbal).

DISTRIBUTED COORDINATION

When teams are separated physically, this puts even more strain on the coordination process. The solution to the obstacle to communication seems to be implicitly understood by familiar teams. Given physical separation [20], the strategy for familiar teams seems to be "more is less". A SMM of team members enables familiar teams to push information, increase the number of transfers when separated and, contrary to within teams, enhance the overall communication strategy by communicating more when the workload increases [20].

COORDINATION IN NOVEL SITUATIONS

When teams that have a SMM of team members face a novel situation [21], they implicitly understand there is a need to learn, and they act accordingly ("we do not know and have to learn — together"). In such situations, teams that have a SMM of team members have 2 parallel communication strategies. Initially, when the uncertainty is greatest, it is crucial to create a common understanding of the surroundings. Hence, they adjust (implicitly) and become more explicit, make more statements per minute and use closed

loop communication to develop a SMM of the equipment, task and interaction. The need to be explicit is reduced as the team learns the task. The second strategy seems to be to dynamically allocate task-relevant resources to team members to take care of workload distribution problems by giving more backup and engaging in adaptive behaviour.

OUTCOMES

The shipmate model suggests that familiar teams approach a dynamic environment differently from unfamiliar teams. First, familiar teams seem to be more attentive (higher heart rate during low workload [20, 21]), more resilient (lower heart rate during high workload [19]), and adaptive (decreasing heart rate during novel situations, 2 and recovery [20]). A SMM of team members seems to enable familiar teams to act more quickly and more thoroughly and to achieve greater mission success (e.g. more hits).

STAFFING, SAFETY AND TRAINING

The shipmate model has implications for the rotation of personnel in expert teams. Mastery of rules, procedures, and skills is not enough for high performance by a team. Personnel need to develop a SMM of the other team members. Keeping teams intact during training and operations could be a way of achieving this.

Consequently, there are implications for staffing. The findings indicate a policy of promoting stable team membership. When the question of replacing a team member arises, one solution could be to choose between potential candidates based on their familiarity with the team in question. Training (e.g. a simulator) should also be conducted collectively as a team prior to actual performance, and not individually as is the case in many organisations.

It is obvious that it is almost impossible to avoid rotation. Unfamiliarity will therefore always be present to a greater or lesser extent. But the findings can contribute to a higher level of safety by proposing that SCO should avoid putting together unfamiliar teams in situations where a possible novel and critical situation may occur before they have had time to operate together for some time. If this is impossible, one recommendation would be to use the first occasion on which they are assembled to obtain vital information about each other and to spread it throughout the team. The findings indicate that a SMM of team members enhances a team's sensitivity to change (ref. the proposed shipmate model). A crucial issue for a newly formed team to attend to would therefore seem to be to increase and share awareness of how each team member reacts to a high workload and uncertainty. Second, knowing when to use closed loop communication will be crucial in relation to making sure that everybody understands and learns as a situation unfolds and develops. Similarly, each team member must understand and engage in behaviour such as mutual performance monitoring, backup, and adaptability. Following the logic of Espevik et al. [19–21] findings, a newly formed team will be able to learn more quickly and adapt better to high workload situations.

If team members are trained to make proper plans, prior to and during an activity it will eventually enhance performance. One way is to train them to set goals, create an open environment, share information related to task requirements, and clarify each team member's role and responsibilities. This will help team members to build situational awareness and SMM, thereby enabling teams to better coordinate their activity [15, 24].

Cross training refers to a strategy in which each member is trained on the task, duties and responsibilities of his or her fellow team members. The goal of this type of training is to provide team members with a clear understanding of the entire team function, and how one's own particular task and responsibilities interrelate with those of the other team members. This will eventually create SMM that enable each team member to anticipate the information the other team members need, enhance co-ordination and reduce the need for communication among teams. Volpe et al. [13], and Cannon-Bowers and Salas [25] showed the effects of cross training on 3 different studies.

In team self-correction training, teams review events, correct errors, discuss strategies and plan future events. In this kind of training, it is important to state the learning objectives and, based on these goals, correct attitudes, behaviours and cognitions. It also gives the team members the possibility to provide feedback and learn SMM of team members. Feed-back ought to be given in a non-threatening manner, and include suggestions for prevention in the future [26].

CONCLUSIONS

Espevik et al. [19–21] have demonstrated that knowledge about team members (i.e. a SMM of the team members) adds to performance (i.e. coordination and communication), efficiency (accuracy, latency and mission success), and resilience (i.e. hearth rate) over and above the contribution of operational skills. This confirms SMM of team members as an important and independent construct with an added value in relation to team performance and efficiency. It thereby expands previous knowledge, where the focus has been on equipment, tasks, and team interaction. The findings represent a contribution to and fill in a vital gap in the SMM literature and they have implications for training, staffing, and safety issues for teams in safety-critical organisations.

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