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Interaction of individual and team performance in ship command centres

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SUMMARY

An assessment of a fully operational command centre performing under high pressures in information load, time stress and cognitive complexity has shown that in particular, four factors play a crucial role: individual information processing, team management, communication load and the distribution of tasks. It is concluded that individual processes and team processes compete with each other. If individuals are getting loaded then first those tasks will be dropped that are demanding and do not lead towards direct feedback. Team tasks suffer most under these conditions.

KEYWORDS

Command centre, team performance, observational methods, performance evaluation, workload

1 INTRODUCTION

Recently, the Royal Netherlands Navy has launched several studies for the analysis and design of the operational effectiveness of command crew. These aim at understanding better the critical requirements of command centres. An important driver of these studies is the need to optimise crew size and operational performance. In this presentation I will focus on the assessment of the current M-frigate class command centre that was performed in 1998 by a team of researchers of TNO Human Factors.

The attention towards command crew effectiveness is one that fits a gradual development of human factors studies for the Dutch Navy. These had an early focus on workplace ergonomics, and developed gradually into interface design and common visual spaces, into assessment of the human-machine complex in the current command arrangement and for future command centres. In parallel, efforts are being employed to structurally

incorporate human factors in the broadest sense into the conceptual development and the design process (Human Systems Integration, US DOD 5000.1, 1992; UK Human Factors Integration Program, D/DOR (Sea), 1991; Beevis, D., Essens, P. & Schuffel, H., 1996).

Command centres

A command centre (operations room, or combat information centre) of a frigate is a typical example of a complex system where information from different 'worlds' (air, surface and subsurface) is gathered, analysed and acted upon.

A command centre can be characterised as a 'human activity system' (Checkland, 1993) designed for human information processing, decision making and execution supported by technologies such as interfaces to sensor and weapon systems, and combat information system. The system is built to respond to a wide variety of situations and signals from external worlds, that are dynamic and change with varying time horizons. The system is complex because it is comprised of multiple people and multiple technologies organised in several subsystems. These have to tune their processes and combine and collate the information produced in order to achieve the mission of the ship.

Traditional human factors evaluations of complex prototypes or operational systems usually focus on operator performance instead of performance of the whole system (Meister, 1998), or limits evaluation to a sub-system, such as the human-computer interface, or to a single criterion, such as workload. Outcome measures of the whole system may be used to get an summative view on the performance of the whole system (often referred to as MOEs). The problem is however that a systems outcome approach treats the system as 'black box' (input-output) hiding multiple internal sources of positive and negative effects which lead to some composite

result. Therefore these measures fail to provide an understanding of the factors that generate that outcome. The fundamental problem however is that there is still insufficient knowledge of the contribution of one factor to the outcome of the whole system or what factors contribute most.

2 M-FRIGATE COMMAND CENTRE

The study of the current command arrangements in the M-frigate - the focus of this paper - was driven by the Navy's need to understand better which factors are critical for effective performance in order to optimise *current* command and to incorporate those in the design of *future* ship and command centres.

A command centre in full operation usually displays an impressive hectic and concentrated activity often with intense verbal communications via networks and face-to-face. Assessment of performance under these conditions requires a well developed methodology and instruments that capture the dynamics of the processes and addresses the critical factors of the complex system. Our tasks was to develop such methodology.

Of other studies in Naval command, in particular the TADMUS studies should be mentioned (Cannon-Bowers & Salas, 1998). Similarly to goals in our command studies they study the complex nature of command in dynamic and stressful situations. A difference is that they have focused on the air defence team, while we look at the command centre as a whole representing the mission of the ship.

Moreover, the M-frigate assessment was directed specifically to the factors that determine effectiveness of the current command centre. This will then be used as a baseline for further studies. The assessment does not address the strategic or tactical outcome of decision making, nor the performance of the technologies used, rather it focuses on individual and team processes in information processing and decision making.

Performance indicators

High workload conditions are considered to be 'normal' in an operational command centre. The question is whether workload levels are that high that processing capacity, of individual or team, shows its limits. This would negatively affect performance effectiveness – there is more to be done than can be handled in the time given. A second question is whether workload is evenly

distributed over the crew. If in a critical situation some team members have not much at hand while others are overloaded, then resources are apparently under-utilised. But, not only from an operational perspective is workload an important issue. Also for the crew's appreciation and quality of work: constant performing below expectations will result in negative feelings and consequently in lower performance.

In dynamic event-rich situations measuring workload once at the end of a mission would be insufficient. A continuous review of the workload gives insight how workload develops over time for each crew member, where bottlenecks are in processing capacity, and how workload is distributed over the crew members.

Workload can be used as an indicator of efficient and effective team performance but does not show how well the job is done. Qualification of how well a task is being performed requires insight in how the demands of an operational situation are addressed. In complex tasks one should also take into account that there are parallel tasks to be processed and prioritisation or effective task switching can only be judged in context. This is the role of the domain expert. Judgement of quality should be coupled with critical events in the scenario's which makes it easier to score during a sessions.

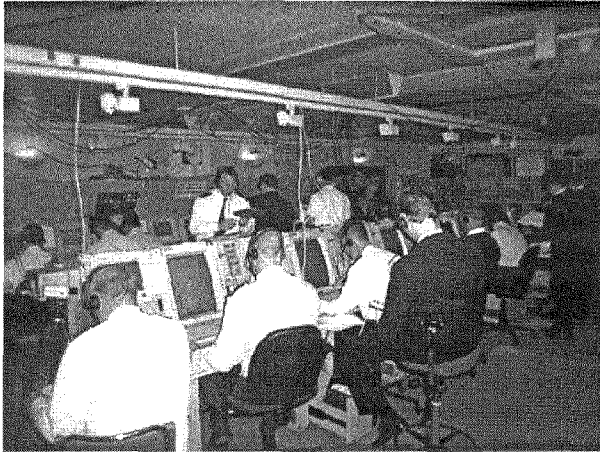
METHOD

Experimental setting

Obviously, in order to assess the effectiveness of a command centre under critical conditions one needs a realistic setting, with realistic scenario's, with a team that is fully operational.

On the other hand, for producing well-founded conclusions, one needs control over the situation, repeated measurement using multiple teams responding to the same situations. Moreover, given time and resources available this has to be done in an efficient way.

We have used the Navy's training facility which has a copy of the M-frigate command centre. The use of matching equipment and layout facilitates the application of skill-based activities so that the teams can perform the way they are used to; only the variations in the scenario's will show in the performance.



The use of a land-based facilities always evokes discussions of the effect of ship movements on the performance. Indeed, ship movements result in fatigue which affects performance. Moreover, there may be effects on team tasks such as communication and team management. A second aspect of reality not easily simulated in a training facility (and in standard sea-based exercises) is the stress of being under attack. It was argued that these factors would certainly add to performance degradation, but that first stress due to time-limits and information-uncertainty should be investigated. In order to augment the validity of the assessment, the findings from the experimental situations were verified during full sea exercises.

Registration of workload

All workstations were equipped with a special keypad with five keys representing a 5-point scale: Most left key represents score 1 defined as 'time left'; most right key defined as score 5 indicating 'too little time'. The middle key (3) was defined as 'just enough time'. The operator's task was to indicate how much time was left for doing their jobs at that very moment. Every five minutes a small lamp on the keypad flashed which cued the team member to give a judgement. Each key press was registered in a computer-system and linked to video registration (Observer system).

Registration of performance quality

Four indicator categories are distinguished: the quality of the information processing of individual crew members, the communications between the team members, the handling and application of the systems and tools, and the management of team by the team leader. The categories cover several subcategories:

- 'Information processing' comprises delay in information processing, overlooking of information, errors in interpretation;
- 'Communications' concerns the correct application of communications procedures, timely communications, interrupting communications;
- 'System handling' covers the ease of operating a system, lack of skills in operation; adequacy of settings;
- 'Team management' refers to limitations, adequacy or overdoing in direction and control.

Seven domain-experts were distributed over the team and observed performance. When they judged during the session that one or multiple categories were applicable in that situation this was scored on a form and with a key press the instance and its weight was linked to the video recording.

Scenario's

Scenario's are sequences of predefined conditions and events. Assessment of a system requires critical events of combination of events that load of even test the limits of the central functions of a system. For a command centre central functions are processing information and making decisions. Three scenario's were developed: a normal workload scenario's of which was expected that a well-trained team could handle without problems; an input information-load scenario with many tracks and information units; and, an information-uncertainty scenario with missing information and unexpected behaviour of the objects in the world.

Scenario design was based on our knowledge of factors that affect information processing and decision making, such as:

- number of tracks and multiple threats or targets, and number of potential measures relate to overload of information handling;
- conflicting information, ambiguous cues, threats, multiple options and criteria, conflicting use of resources relate to cognitive stress and processing capacity;
- insufficient information, misleading or novel situations, limited feedback relate to availability of knowledge and experience.

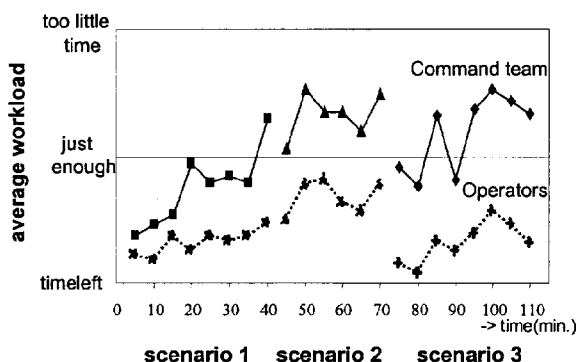
Procedure

Four experienced and fully-operational teams of 16 members each participated in the assessment sessions performing in three scenario's. At the start of the session they received a standard operational briefing which explained the operational situation and mission. Also was explained that measurement

tools were used to get an indication of the functioning of the command centre and that no individual scores were isolated. The scenario sequence was the same for each team: normal, information-load, information-uncertainty scenario. Each scenario took about 40 minutes. Between each scenario was a break. After the session a questionnaire was handed out which addressed the functioning of the command centre on board. Subsequently, in a debrief scenario events and typical performance, actions and decisions were discussed by the team.

RESULTS

Workload data showed that about half of the scores are around the middle level ('just time enough') which can be considered as the standard level of load during operations. One third of the scores was below that level indicating that there was ample time for performing the tasks at hand. One sixth of the scores are above the just enough level indicating that there were instances that there was very little time to perform the task at hand. Overall levels of the scores can be clustered around subgroups in the command centre. It was found that the command team has on average a higher workload than the supporting operators, with exception of a particular subgroup of operators (the electronic warfare operator and controller) who had also a high workload. There was little difference between the two test scenario's. The conclusion is that the unequal distribution of workload found results from an organisation of tasks which, under complex conditions, centralises control with the command team.



Quality assessment of performance showed several opportunities for improvement. Of most interest is the distribution of the scores over the categories. The domain experts particularly judged that team direction and control (35%) and individual

information processing (30%) could be improved; less prominent were system handling (18%) and communications (17%).

The questionnaire showed that internal communications was considered to require a high level of attention (90% of respondents, N=53), and that its volume was considered to be too high (60%). The tasks to be performed are in general time critical and require high attention (88%). System handling could be improved by improving the interface with more direct interaction. In time critical situations any system delay is considered hindering performance.

DISCUSSION

The assessment of the command centre performing under high pressures in information load, time stress and cognitive complexity shows that in particularly, four factors play a crucial role: individual information processing, team management, communication load and the distribution of tasks. An interesting statement from a Naval evaluator describes the combination of these factors most adequately: 'when load increases in the team curtains seem to get shut between team members'.

In trying to understand the combination of factors we distinguished between the structural settings of the command centre and the command and control process itself. Structural is the given quality of the team and their ability to work together. Structural is the distribution of tasks and the work procedures that are predefined. Structural is also the technology used to support or enable the command centre to do its job. These factors are brought into play before the mission starts.

During the operations people are the flexible and vulnerable force and adopt compensation strategies for what is structurally imperfect: a situation most people recognise immediately. From the literature on stress handling a checklist of strategies was derived (Gaillard, 1996):

- first people try to compensate for situations the system was not designed for by putting extra effort into play
- if load rises further tasks for which that is possible are delayed or postponed
- subsequently, focus is on a limited set of tasks; at best the central and most critical tasks
- less communications is observed with an increasing tolerance for errors (correction costs time and effort)

- finally, control over other people is loosened and eventually lost.

This list shows the process that can also be observed in highly loaded conditions in command centres. It shows that individual factors and team factors interact with each other in an understandable way. If individuals are getting loaded and then first those tasks will be dropped that are demanding and do not lead towards direct success or hinder their most direct responsibilities. Team tasks can be considered to be such tasks. In particular when team leaders have also other tasks than direction, control and co-ordination the danger is that they will do the direct accountable tasks first and postpone other tasks to later. Eventually this may result in a breaking down of the team as a whole.

In conclusion, the following factors are considered critical for effectiveness:

- Organisation of processing capacity: focussed on optimised task distribution; flexibility in task allocation; reduced communications
- Quality of people / team: focussed on training as a team; training graceful degradation in order to deal with overload situations; training in complex and varied situations
- Technology: focussed on directness in interaction and response; support in handling information.

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