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# Analyzing fatigue, stress and human errors in Emergency Operation Centre management: The consequences of using different cognitive modelling frameworks

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Emergency Operation Centres (EOCs) are responsible for planning and responding to large scale disasters, such as Katrina, Fukushima, or any large earthquake. An EOC is a central command for coordinating the different field assets (e.g., fire, police, ambulance, social services). It is usually composed of several individuals (EOC managers), each of whom has a designated set of tasks, such as communication, logistical support, mapping events, writing reports, as well as a manager who is in charge of coordinating everything. EOC mangers normally do not directly control field assets; instead the managers pass on information and make strategic recommendations.

EOC organization and training is based on guidelines issued by government bodies, such as FEMA in the US. However, EOC performance is very difficult to study because massive disasters are infrequent and there is very little data available afterwards. Also, it is highly problematic and expensive to realistically simulate disasters in the lab. Cognitive modelling provides a pragmatic avenue for addressing this issue in lieu of directly studying EOC managers under realistic conditions.

However, all cognitive modelling is not the same and different cognitive modelling frameworks are likely to generate different types of recommendations. Because of this it is important to consider the range of cognitive modelling frameworks at the outset of a project, to avoid using a single framework that might generate poor or dangerous recommendations. Different cognitive modelling frameworks can be treated as different ontological and/or epistemological systems (i.e., what is the nature of the object of study and how best to understand the object of study, respectively). By conceptually analyzing how each framework applies to the project a better sense of the project as a whole can be developed and cognitive modelling can be deployed more effectively.

In this short paper we have applied this methodology to understanding how to tackle the problem of fatigue in EOCs. One of the main principles of EOC management is to protect the first responders (e.g., firemen, police, ambulance). So, if a building has collapsed and is unstable, first responders should not be sent in if there is a chance of further collapse, even if this means that those needing immediate help will die. The reasoning behind this is that if the first responders die then there will be no one to help the others. This reasoning can be extended to fatigue and stress within the EOC. That is, although they are not in physical danger, EOC managers are in danger of mental fatigue, which could lead to serious mistakes or misjudgments.

## General Guidlines

One solution that has been proposed is to use models of fatigue to generate generalized guidelines for breaks and then enforce the breaks. This would involve having a mental health professional, or someone trained to monitor for fatigue on the team, and giving them the authority to enforce breaks.

## Cost/Benefit

Using enforced breaks could reduce fatigue but, even if we assume mental health professionals can effectively discern fatigue *and* that the other EOC workers will obey them, there is still an issue. The model should be framed in terms of a cost benefit analysis, where the benefit is avoiding errors caused by cognitive fatigue and the cost is the information lost when a manager is replaced with another manager. That is, loss of information can also result in serious errors.

## Human Factors/HCI

A major component of EOC management is logging the ongoing flow of information. In theory this should mitigate the problem of information loss when an EOC manager needs to rest. Information logging is an area where Human Factors studies and Human Computer Interaction evaluations can be used to develop more efficient systems for logging information. This would both improve information transfer and reduce fatigue due to poorly designed systems.

However, focusing on individual systems instead of looking at the whole picture can lead to premature optimization (Knuth, 1974). That is, improving the efficiency of the parts may only produce small, insignificant improvements overall, and it could even make the whole system worse (Gray et al, 1993). In the case of the EOC, although logging information is an important part of EOC management, the purpose of the EOC is to integrate information and maintain a functional awareness of the overall situation. This is not something that cannot be logged in the same way as specific events. Therefore, improving the efficiency of logging specific events needs to be done within the context of maintaining a common ground (Klein et al, 2004) situational awareness.

## Unit Tasks

Cognitive modelling methodology often proceeds by first identifying the unit task structure and then modelling the individual unit tasks. Unit tasks are theorized to divide up a task into parts, such that the cognitive system is not overloaded and down time is avoided (Card et al, 1983). Specifically, unit tasks are designed so that all of the information needed can be processed by the cognitive system in real time (avoid overload), and so that unit tasks do not get hung up waiting for something to happen when the agent could be getting something else done (avoid downtime). More recently, it has been proposed that unit tasks are also designed to avoid interruptions. That is, a unit task will be of a size such that it is likely that it will be finished without interruption (West & Nagy, 2007).

If we take the unit task concept seriously, it provides an important insight. Specifically, if EOC managers consider resting as downtime, and not an integrated part of the management task, then they will tend to have unit task structures that avoid it. This makes sense as many EOC managers are drawn from police, fire, or ambulance services where it is unusual to have emergencies that last more than a few hours, so they can normally rest after completing their tasks. Under these conditions, treating rest as downtime and minimizing it makes sense. These professionals are often chosen as EOC managers because EOCs need people who are fast and efficient when required. So anything that interferes with that could be problematic. Importantly, this may include enforced breaks and unfamiliar logging methods.

## Macro Cognition

Macro cognition can involve a number of different methods and theoretical approaches, however, we will focus on the SGOMS modelling framework, as it seems particularly useful for understanding EOC management. A planning unit is an SGOMS structure that serves a similar purpose as the unit task. Whereas, unit tasks are a control structure (Card et al, 1983) for protecting the integrity and efficiency of the *micro* cognitive architecture (e.g., memory, attention, motor actions, perception, etc.) planning units are a control structure (West & MacDougal, 2015) for protecting the integrity and efficiency of the *macro* cognitive architecture (e.g., planning, cooperation, interruptions, reacting to unexpected events, etc.). Planning units can be thought of as a way of managing unit tasks in that the appropriate unit tasks need to be completed to complete a planning unit. In this sense, planning units control the flow of unit tasks. However, unlike unit tasks, planning units are designed to be interrupted and restarted. Importantly, planning unit choice is based on context and situation awareness.

From this perspective, the problem is that EOC managers do not have a rest-break planning unit. As noted above, there is no reason why they would since extended rest-breaks are not part of the normal routine in police, fire, or ambulance services. Resting should be a specific planning unit, just as logging information would be a specific planning unit. A model of how best to do this could be used as the basis for designing a training program. A resting planning unit would be triggered by downtime and would contain relevant unit tasks such as: locate a place to rest, inform colleagues about rest, arrange for someone to cover your post, arrange for when your rest should end, and pass on any important information.

# Conclusions

We have analyzed the problem of fatigue in EOC workers using various different modelling frameworks as ontological and epistemological tools. Each solution seems reasonable when viewed in isolation but, in fact, they may produce solutions that are problematic. Using a model to say when a rest break should be enforced is a responsible and principled way to implement this policy, but this policy could lead to serious problems if information transfer is ignored. Using Human Factors and HCI to improve information logging could ameliorate this, but these solutions need to be evaluated in the broader context of maintaining a common ground situational awareness. Applying the unit task concept shows why EOC operators avoid downtime but also demonstrates that this is a necessary consequence of having fast, efficient responses. One consequence of this is that care needs to be taken that an isolated solution or improvement doesn't lead to a less efficient overall system (e.g., as in Gray et al, 1993). Finally, the planning unit concept suggests that the focus should be first on training rather than enforcement or systems efficiency.

The more general point we are making is that applied cognitive modelling should involve an initial assessment of the whole task to get a broad understanding of how modelling can be best applied. As we have shown, this can be done by applying concepts drawn from the field of cognitive modelling itself.

# References


Card, S. K., Newell, A., & Moran. T. P. (1983). The Psychology of Human-Computer Interaction. L. Erlbaum Associates Inc. Hillsdale, NJ.

Gray, W. D., John, B. E., & Atwood, M. E. (1993). Project Ernestine: Validating GOMS for predicting and explaining real-world task performance. *Human Computer Interaction*., *8*(3), 237-309.

Klein, G., Feltovich, P. J., Bradshaw, J. M., & Woods, D. D. (2004). Common ground and coordination in joint activity. In W. B. Rouse & K. R. Boff (Ed.), Organizational Simulation. (pp. 139-184). New York City, NY: John Wiley.

Knuth, D. (December 1974). Structured Programming with Goto Statements", *Computing Surveys* **6**:4, pp. 261–301

West, R. L., & Nagy, G. (2007). Using GOMS for Modeling Routine Tasks Within Complex Sociotechnical Systems:Connecting Macrocognitive Models to Microcognition. Journal of Cognitive Engineering and Decision Making

West, R. L., & MacDougal, K. (2015). The Macro Architecture Hypothesis: Modifying Newell's System Levels to Include Macro Cognition. *Biologically Inspired Cognitive Architectures*.