Title: A new model of the impact of human factors on risk assessment in emergency services: The Dynamic Cognitive Risk Assessment Model (D-CRAM©).

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Abstract:

The problem of how the impact of human factors on risk assessment is modelled and how operators can be trained to better assess operational risk is a perennial conundrum among emergency service organisations. Emergency services have taken up such models as Endsley's model of Situation Awareness and have instituted training in models of Dynamic Risk Assessment. None of these models, however, take account of the human factors in risk assessment which lead to operator error, nor do they identify best practice in performing risk assessments. Previous research by the authors suggests that Dynamic Risk Assessment models commonly employed by emergency services are unreliable and variable in practice. The authors propose a new model of risk assessment which: a) identifies the key steps in performing an operational risk assessment; b) identifies the typical cognitive biases likely to impact on the performance of an operational risk assessment; c) identifies behavioural and decision-making techniques which contribute to effective risk assessment. Rather than being purely theoretically driven this new model is based on a body of research that accounts for the typical limits of human information processing capacity and research into the performance techniques of expert emergency service operators.

Introduction

It is generally accepted that personnel working in emergency response face changing and dynamic situations that present challenges to effective risk management. Previous research shows that what is perceived in the emergency response environment as a risk varies from one individual to another (Holgate & Clancy, 2007) and that the identification of risk is essentially subjective (Adams, 1995, Reason, 1997, Clancy, 2005) and prone to numerous cognitive biases and errors (Sadler, Holgate & Clancy, 2007). Adams (1995) highlights the problem by noting that *"The future is uncertain and inexplicably subjective; it does not exist except in the minds of people attempting to anticipate it."* (p.30)

Whilst the concept of assessing risk in complex and changing environments has been a process that has no doubt been practised over the history of humanity, in more recent years the need for emergency services to provide evidence that people have been trained in this area has changed. Emergency services have been one domain where safety authorities have been seeking evidence that responders are trained to identify and assess risk as part of a 'size-up' process. As already mentioned, there are a couple of significant problems with this process, firstly risk is subjective and when something does go wrong, hindsight is used to determine whether actions were appropriate. We argue that this approach is flawed as it fails to take into account the limitations on human information processing and the environmental impacts at the time, such as time pressure, noise, visual cues and how much information the operator has available. Another area that presents challenges is that it is a difficult process to assess risk perception validly once training has been provided. How does one validly measure whether an individual has grasped the training provided when risk perception is a cognitive process which will vary depending upon the situation.

The most common model of the risk assessment process in use today is that developed by the fire services in the United Kingdom in the early to mid 1990's (Flin, 1996). This has been

further applied by police forces in the United Kingdom as a means of training personnel to identify risk in changing environments, develop strategies and act. This approach by the UK fire services was driven by a high rate of firefighter fatalities in the 1980's and 90's following a number of improvement notices being served by the Health and Safety Executive on the fire services (Flin, 1996). In the late 90's and early 2000's fire services in New Zealand and Australia adopted the British style approach or adaptations of the British model (Clancy, 2005). The existing models of dynamic risk assessment followed Endsley's (1995) modelling and research into situation awareness in the military environment (see Endlsey, Holder, Leibrecht, Garland, Wampler & Matthews (2000) for an extensive review of this research). While this research was pioneering the resulting models of dynamic risk assessment have been criticised for their lack of empirical support. Tissington & Flin (2004) found that *"…the most serious area of criticism of this model – or indeed any other description of risk assessment as a clear step by step process – is that dynamic risk assessment is inextricably linked with decision making."* (p.8). Tissington & Flin (2004) further point out that *"…the model is the product of the expert view of a small number of fire officers which, given the expert nature of risk assessment, is on the face of it appropriate. However, no replicable methodology is reported for the organisation of the model nor has it (to date) been tested empirically."* (p.9). Following an extensive review of the theoretical and applied literature and research the authors developed the Dynamic Cognitive Risk Assessment Model (D-CRAM) in an effort to address the lack of empirical support for existing models of dynamic risk assessment.

Any attempt to model risk assessment must take into account the limitations of human information processing and, in particular, the limitations of working memory. Working memory or short term memory restricts an operator's information processing capacity, it is this area that acts as a mental "scratch pad" and holds information on a temporary basis (Miller, 1956). It was concluded by Miller (1956) that working memory capacity is limited to only 7 pieces of information, plus or minus 2 and in situations where the operator is working under stress this capacity will reduce (Baddeley, 1972). This highlights the need to ensure that any models of risk assessment are not of such complexity that they exceed what would be the reasonable limits of working memory in a complex situation.

The 'Dynamic Cognitive Risk Assessment Model (Holgate & Clancy, 2007) illustrates the cognitive steps involved in the risk perception process and provides a simplified risk rating matrix based on a 2 x 2 (likelihood/consequence) model. The matrix is an important component in the process, particularly in educating operators and in reducing the effect of subjectivity of risk scoring. Previous research by the authors (Clancy & Holgate, 2005) found that the 4 x 4 risk assessment matrix used by emergency services failed to provide operators with any level of consensus. The matrix currently used by emergency services provides 16 potential categories of risk and when 110 fire-fighters were asked to provide a risk rating for a fire fighting scenario based on the commonly used fire service (4 x 4) matrix out of 16 possible categories respondents endorsed 11 (Clancy & Holgate, 2005). Clearly this amount of variability in risk ratings between operators has to be reduced if risk ratings are going to serve any purpose at all.

Key steps in performing an operational risk assessment

1. Evaluate the environment

Consistent with Endsley's (1995) model of situation awareness we argue that the first steps in performing a risk assessment are a proper evaluation of the elements of the environment. Experts are noted for their ability to understand the deep structure of a problem (Ericsson & Lehman, 1996) and expert emergency service operators have long emphasised the importance of taking sufficient time to perform a proper situation assessment before acting (McLennan, Omodei, Holgate & Wearing, 1007). The greatest

risk at this stage of the assessment process is an incomplete understanding of the nature of the situation due to the rush to intervene felt by many emergency service operators. The way in which the situation is framed will also affect operator's evaluation of the environment. Sadler, Holgate & Clancy (2007) found that some firefighters perceived a fire described as contained to be less risky than a fire described as going and even expert firefighters have been found to form different expectations of fire behaviour depending on whether the fire was described as a wildfire or a prescribed burn (Lewandowsky & Kirsner, 2000). In order to counter the risk of framing effects or an incomplete comprehension of all of the elements of the environment operators should take sufficient time to properly evaluate the environment. Even taking just a few extra minutes is likely to make a substantial difference to an operators comprehension of the nature of what they are dealing with.

2. Prediction

Again consistent with Endsley's (1995) model we argue that anticipation of future states of the environment and forming a prediction as to how events are likely to unfold is the next stage of the risk assessment process. The cognitive error most likely to occur at this stage is an optimistic bias in predictions, which assumes that the situation will not substantially deteriorate (Metcalfe, 1998). The death of 13 firefighters at Storm King Mountain where the firefighters decided to continue operations despite a clearly deteriorating situation (McLean, 1999) would appear to offer an example of the operation of an optimistic bias. Research suggests that one characteristic that distinguishes effective emergency service operators is their explicit anticipation of a worst case scenario in their prediction of unfolding events (Johnson, Cumming & Omodei, 2007). If the firefighters on Storm King Mountain had anticipated a worst case scenario they may have made different decisions on the day.

3. Plan

The next stage in the risk assessment process is the development of a specific plan to deal with the emergency situation. Typical errors at this stage are the assumption that one plan will be sufficient to deal with the situation and/or the assumption that circumstances will not change unexpectedly. The "planning fallacy" refers to our tendency to underestimate the amount of time a job will take and this cognitive bias has been found to be pervasive throughout human endeavour (Sanna, Parks, Chang & Carter, 2005) and emergency service planners are not immune to this bias. Another bias found specifically among emergency service planners (McLennan, Omodei, Holgate & Wearing, 2007) is a so-called overutilization or resources bias, that is, the tendency for emergency operators to assume that all problems can be solved by throwing more resources at the situation and a tendency to use all resources that are available regardless of the utility of doing so. There are many examples in emergency services of unanticipated changes in the situation rendering existing plans redundant. In addition to explicit anticipation of the possibility of a worst case scenario we claim that effective operators should explicitly assume that their Plan A will fail and develop a Plan B fallback position.

4. Assess

The next stage of the model is the assessment of the risks involved in executing plans. It's at this point that the simplified 2 x 2 risk rating matrix can be applied. Instead of offering an unwieldy 16 separate categories (as in currently used dynamic risk assessment matrices) we argue that a traffic light model of risk assessment is likely to provide a more workable heuristic (stop, go, proceed with caution) for risk assessment that will arguably result in greater consensus between operators in emergency environments. Previous research has shown an important difference between experienced and inexperienced decision-makers in assessing their planning (Klayman, 1995). The inexperienced show a confirmation bias in

that they selectively seek and attend to evidence which confirms the correctness of their decisions while ignoring evidence that suggests that they are wrong. Experts, on the other hand, actively seek evidence that they are wrong (Ericsson & Lehman, 1996). Effective emergency managers will therefore seek evidence that disconfirms their assessment that their planning is safe.

5. Review

An important aspect of Endsley's (1995) model of situation awareness is the point that maintaining situation awareness is a dynamic process that requires constant vigilance to changes in the situation and constant updating of an operators comprehension, anticipation and planning. Once plans are decided on and pursued one of the most pernicious biases may occur and that is sunk costs bias (Karlsson, Garling & Bonini, 2005), that is, the tendency for operators to continue to pursue an original plan that is clearly not working due to the time, effort, resources and psychological investment that has already gone into the plan. It is at this stage that an effective operator will recognise a deteriorating situation, cut their losses and adopt their fallback position.

Discussion

We argue that the strengths of our proposed new model of risk assessment are that it: a) identifies the key steps in performing an operational risk assessment; b) identifies the typical cognitive biases likely to impact on the performance of an operational risk assessment; c) identifies both effective and ineffective behavioural and decision-making techniques which contribute to effective risk assessment. Rather than being purely theoretically driven this new model is based on a body of research that accounts for the typical limits of human information processing capacity and research into the performance techniques of expert emergency service operators. This represents an extension of models of situation awareness and an improvement on existing risk assessment models. We believe that training in the application of the D-CRAM process could significantly enhance emergency service operator's ability to assess risk and make appropriate decisions. Future research by the authors will test whether the 2 x 2 traffic light matrix of risk assessment results in greater consensus between operators than the currently used 4 x 4 matrix.

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