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Human Information Processing aspects of Effective Emergency Incident Management Decision Making

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“The key is control: control of our attacks; control of our defence; and control of ourselves in the face of disaster.” (Rear Admiral Woodward, Falklands campaign, evening of May 4, 1982, following the loss of HMS Sheffield to an Exocet missile attack)

Introduction

This paper reports findings from a program of research investigating the effectiveness of emergency management decision making by fire officers who were on-scene commanders at fires and related civil emergencies (eg, hazardous chemical discharges and building collapses). The aim of the research was to improve understanding of psychological processes associated with effective decision making in complex, dynamic, time-pressured, high-stakes, multi-person task environments—such as military operations, transport control, and manufacturing and industrial plant operations.

Significant advances in communications and fire suppression technologies over the last 10 years have changed dramatically the nature of firefighting operations, in both urban and wildland settings. However, emergency management operational activity—especially local incident command activity—remains a fundamentally *human* endeavour. It involves hierarchical teams of trained individuals, using specialised equipment, whose efforts must be coordinated via command, control, and communication processes to achieve specified objectives under conditions of threat, uncertainty, and limited resources, both human and material. The command and control function exercised by the on-scene, or local, incident commander is crucial to success.

In the program of research reported here, we endeavoured to focus on identifying those decision processes associated with more versus less effective incident command. Effective incident command obviously requires considerable technical knowledge of fire chemistry and physics, suppression equipment capabilities, and standard operating procedures. However, previous work by Omodei and Wearing (1995) suggested the importance of another set of psychological capabilities which could perhaps best be described as **information processing competencies**.

We explore these by presenting some general conclusions reached about the decision processes of experienced fire officers in local command at fires and related emergencies by comparing processes of more versus less effective incident commanders in a range of studies employing diverse methodologies.

Methodologies

The research program utilised several methodologies. These have been described in detail elsewhere and illustrative references are provided. For each methodology, the means by which judgements of commander competence were arrived at is noted.

- Analyses of 20 detailed fire-related death and injury investigation reports (eg, United States Department of Agriculture Forest Service, 2001)—consensus judgements by domain experts.
- Naturalistic field observation and post-incident interviews with urban fire officers (McLennan, Omodei, & Wearing, 1996)—judgements by peers.
- Structured retrospective interviews with wildland fire service officers (Holgate, 2003)—judgements by peers and by superior officers.
- Twelve head-mounted video-cued post-incident recall interviews in urban operational settings (McLennan, Omodei, & Wearing, 2001)—judgements by peers.
- Twenty nine head-mounted video-cued post-incident recall interviews in two urban simulation exercise settings (McLennan, Pavlou, & Omodei, in press)—performance ratings by an expert panel.
- Six laboratory experimental studies of incident command team processes for managing wildland fires, using the Networked Fire Chief computer-generated microworld simulator (Omodei, Wearing, McLennan, & Clancy, in press)—objective indices of team performance in terms of percentage of assets saved.

Decision Processes of Good Incident Commanders

We begin with a negative finding: we have so far failed to find evidence of an obvious ‘personality type’ associated with good incident command. We found our good incident commanders to range from calm and phlegmatic to excitable and talkative, from aloof to gregarious, and from reserved to extroverted. It seems that good incident command is less a matter of what kind of person a commander *is* than what he or she *does* while in command.

At a surface level of description, first, good incident commanders quickly extracted the most relevant (and not necessarily the most salient) features of the situation from the array of information at hand or available. Sometimes this required active search for information deemed to be ‘need-to-know’. They purposefully scanned both central and peripheral features of the information array to ensure they had accounted for all relevant features of the environment. The information array often comprised conflicting items, and items of doubtful reliability in terms of accuracy or timeliness. Second, these commanders then rapidly developed a conceptualisation, or mental model, of the core of the problematic situation confronting them. Third, they speedily chose a response with a high probability of being implemented effectively, having regard to the level of threat and the resources available. Fourth, they monitored changes in the situation closely in anticipation of likely problems, changing both their conceptualisation of the problem situation and their response tactics quickly as circumstances dictated. Thus far, we have simply provided a description. The challenge is to go beyond this and to identify those processes which enabled these incident commanders to function so effectively while other incident commanders in comparable situations failed to do so.

In comparison with less effective incident commanders, the good incident commanders functioned as if they had a good practical understanding of the limitations of their information processing system, and the corresponding limitations of others. In particular, they operated in such a manner that (a) their effective working memory capacity was not exceeded, (b) they monitored and regulated their emotions and their arousal level, and (c) they communicated with subordinates in ways which took into account subordinates’ working memory capacity limitations. The foundation of their ability to manage their own information load effectively seems to be prior learning from past experience. In summary, good commanders (mostly) knew what to look for and they knew what to do once they found it. This ability was not simply a matter of “years on the job”. While none of the good commanders had less than three years experience in the incident command role, beyond this there seemed to be only a weak association between amount of experience and performance. (Within firefighter culture the

difference between learning from experience and merely participating is well recognised. A dismissive evaluation of the form: “*So, he is supposed to have 10 years experience—or has he just had one year’s experience 10 times?*” is heard regularly). The crucial issue seemed to be that good commanders had reflected at length on the effectiveness of their past performances and developed mastery of their craft in the form of extensive rule-based decision making ability (Rasmussen, 1983). These learned rules allowed the commanders to mostly use fast, robust **recognitional** decision processes rather than slow, vulnerable **analytical** problem-solving processes which are very intensive of working memory capacity. We suggest that such rich networks of learned rules enabling use of recognitional decision processes form the basis of what Adams and Ericsson (2000) characterised as **procedural expertise**.

Some emergency situations were sufficiently complex to preclude the use of simple recognitional decision strategies. Such situations were characterised by one or more of the following: novelty—the officer had never encountered such a situation before, opacity—needed information was not available, resource inadequacy—the resources currently available were not sufficient to permit an optimal response.

In such complex situations, good commanders were often able to transcend their, necessarily limited, range of specific past experiences and use fast, robust **analogical** decision processes to apply previous learning to novel situations. For example, an incident commander was confronted by a serious leak from a large container of liquid oxygen in the grounds of a hospital. He had never encountered an incident involving cryogenic material before. He reasoned by analogy that the best thing to do was to handle the emergency by treating it as he would a volatile toxic flammable chemical leak. The emergency was speedily contained and resolved, though some of the precautions he took were, in fact, unnecessary (eg, ordering his crews to wear Breathing Apparatus)

In other situations characterised by high levels of uncertainty incident commanders were forced to use analytical knowledge-based problem solving processes in order to choose an option from among a set of alternatives. Under such circumstances good commanders used a small number of simple and robust heuristics to guide rapid decision making about what action to take. Two heuristics in particular were used often. The first was that of **minimaxing**: selecting the action least likely to lead to the worst outcome. “*Anyone in the warehouse was probably dead by now. I’ll start a crew in Breathing Apparatus organising the evacuation (--from an adjacent child care centre--). I don’t want a kindergarten of dead kids*”. The second was that of **means-ends-analysis**: when unable to deal with the total situation immediately, using available resources in such a way as to contribute to a complete solution later. “*Even though there are people unaccounted for (--in the motel--), I won’t start a search yet. There are 140 rooms. I’ll put the crew to containing the fire and when the next two appliances come on-scene I’ll start the crews on search*”. Analogical decision processes and simple heuristics may well be a basis for **adaptive expertise** (Adams & Ericsson, 2000).

Good commanders took active steps to control both the type of incoming information and the rate at which it was presented (Table 1). They did so (face-to-face and radio) by (a) asking for specific information they believed to be most relevant, (b) delegating particular individuals to find out and communicate needed-to-know information, (c) delaying receipt of less immediately relevant information. On occasions, they cut-off eager subordinates wishing to contribute to the decision process by stating that the issue being raised could be dealt with later.

Good commanders reduced the load on their working memory by writing down reminder notes and incident management plan steps on whiteboards, post-it notes, clipboard pads, or the vehicle windscreen!—whatever was available. They gave closed, rather than open-ended, orders wherever possible. For example: “*Take a team of two in Breathing Apparatus and check that the (hospital) ward has been completely evacuated, no-one left behind. When you have done that, report to Station Officer Smith, the Sector One Controller, for further*

instructions". In contrast, less effective commanders often gave orders in such a form as to require them to keep in mind where they had sent crew and risk losing track of where resources had been deployed.

Good commanders attempted to anticipate developments in the situation rather than being forced to react to changes: they endeavoured to "stay ahead of the action". As one wildland firefighting service officer interviewed put it: "*You don't fight the fire in front of you, you fight the fire you're going to have in an hour from now*". In particular, they attempted to simulate mentally how the situation could go wrong. They reminded themselves of their major working assumptions (such as wind speed and direction, probability of success of particular fire-suppression activities, and availability of equipment) and made plans for changing tactics if these assumptions proved to be false.

Good commanders monitored their level of physiological arousal and their level of negative emotions (anxiety, frustration, helplessness) and they used these as indicators of their subjective level of mastery of the situation. They used active processes to prevent arousal level and negative emotions from disrupting their decision processes: physical activity; deliberate physical methods of relaxation—muscle tensing and relaxing, calm breathing; and positive self-talk

Decision Processes of Less Effective Incident Commanders

It is tempting to say that poor incident commanders simply lacked the characteristics displayed by the good commanders. However, that would not necessarily be helpful and some characteristics seemed to be associated particularly with (relatively) poor performance.

First, poorer commanders seemed to have fewer decision rules to draw upon. They were less likely to use rapid and robust recognitional decision processes and more likely to employ problem solving approaches. Their lack of available rules to guide sizing-up a situation meant that they were likely to be swamped with information, all of which had to be attended to to some degree, so that situation assessment was slowed. Very salient information was likely to be given undue importance and other highly relevant information was likely to be overlooked. Where relevant information was not immediately at hand, its absence was often not noted and active steps to search out the missing information were not taken. As a result of these processes, commanders' situation conceptualisations were likely to be both slow to develop and inadequate in important respects.

Poor commanders often gave the impression of, and sometimes described themselves as, being overwhelmed by the circumstances of the situation. They reacted to developments in an *ad hoc* manner and found great difficulty in formulating a coherent plan to coordinate activity. Resources were often not used effectively: crews were left idle for periods, and excessive resources were deployed to "side shows" while crucial aspects of the situation were neglected, without such problems being noted and remedied. Poor commanders were particularly prone to being surprised by changes in the situation, feeling disconcerted, and responding rather slowly to the new circumstances. It appeared that all their cognitive resources were fully occupied with the immediate situation: they had no cognitive capacity to devote to planning or anticipating.

Some of those interviewed acknowledged that they felt anxious and unconfident. They described how they found it very difficult to concentrate on the tasks at hand because intrusive task-irrelevant self-critical thoughts kept distracting them and interfering with their concentration on the tasks at hand (Tables 2 & 3).

Decision Processes Associated with Disastrous Incident Command

We use the descriptive "disastrous" for those circumstances where life has been lost, injuries have been sustained, or there has been serious damage to property or the environment which, in the opinion of domain experts, could and should have been avoided. We readily

acknowledge that the causes of such disasters are complex, often involving organisational failures of a systemic kind rather than being simply the fault of the unfortunate on-scene commander (Reason, 1990). Nevertheless, from careful analysis of post-incident investigation reports and retrospective interviews with those involved in ‘near misses’ (when a disaster is narrowly averted by good luck rather than by good management) some characteristics of disastrous incident command appear to be identifiable. The first of these is seriously flawed conceptualisation of the situation and a resulting inappropriate choice of tactics. Often this results from key information being overlooked or misinterpreted through inexperience or lack of training. For example, the commander of a fire team with experience in fighting grass fires and structure fires but no experience in fighting forest fires is likely to underestimate the danger of being trapped in a high fire intensity burn-over in a forest. Another source of flawed situation conceptualisation results from preconceptions preventing accurate assessment of threat. For example, a (false) belief—and a failure to seek confirmatory evidence—that a predicted wind change has already passed through the area is likely to reduce consideration that a crew may be at risk of being trapped by a sudden future change in wind direction.

Other instances of disastrous incident command may result from insufficient self-awareness of what appear to be more-or-less hard-wired biases in the way we process information so as to make decisions. One of these can be described as a **sunk-costs bias**: persisting with a tactic, which to the dispassionate observer is demonstrably ineffectual, simply because time and resources have already been invested in the tactic. Another such could be described as an **optimism bias**: choosing a course of action which necessitates nothing whatsoever going wrong if it is to succeed. For example, positioning a crew on steep sloping terrain with high levels of burnable material above and below them. Another could be described as a **need for action bias**. Good incident commanders frequently report having to deliberately exercise self-restraint so as not to precipitately commit resources to a course of action before completing a thorough situation assessment.

A final bias which seems to have been associated with disastrous incident command at wildland fires could be described as a **linear rate of change bias**. Human beings seem to be incapable of accurately predicting non-linear rates of change. A range of laboratory experiments confirms this. Presumably, such an ability was not called for in our evolutionary past? Regardless, fire spread rates change dramatically with only modest changes in wind strength or ground slope. The history of wildland firefighter fatalities is replete with incidents in which crew appreciated that they were in danger, but failed to appreciate how immediate that danger was. They delayed escape, in some cases apparently reluctant to abandon their tools and equipment, and the fire overtook them—sometimes quite close to safety.

Conclusions

We do not claim to have made new discoveries about incident command decision processes on the fireground, rather we draw attention once more to important psychological processes underlying effective incident command decision making which are easy to neglect in the face of emerging new technologies. We conclude that the most important psychological ‘drivers’ of an incident commander’s performance involve three aspects of the human information processing system:

- The limited capacity of working memory (Baddeley, 2001).
- Rule-based decision making is appreciably faster than knowledge-based decision making (Rasmussen, 1983).
- Effective decision making is dependent on regulation of arousal level and negative emotions (Omodei & Wearing, 1995).

Accordingly, we propose the following information processing competencies as necessary for effective incident command decision making:

1. Acquiring through experience an extensive set of simple and robust rules to guide situation assessment and decision making across a wide range of operational circumstances.
2. Developing effective means of preventing working memory capacity being exceeded in spite of the high mental workloads likely to be associated with emergency operations.
3. Developing self-awareness in order to monitor both arousal level and negative emotions.
4. Learning effective ways of controlling arousal level and negative emotions.
5. Developing a habit of watchfulness against processes likely to interfere with accurate situation assessment, such as preconceptions and decision biases.

Several other tentative conclusions follow from the findings, including:

- New information /communication systems: Be very skeptical of any such systems which simply present a commander with more information and allow him or her to be more readily interrogated and micro-managed by superiors.
- Selection: Rather than rely on stereotypes of what constitutes ‘commander material’, seek evidence that candidates can (a) manage complexity, (b) learn quickly, and (c) retain a degree of self-control under stressful circumstances. Carefully constructed and evaluated field challenges are probably superior to pencil-and-paper tests of knowledge, aptitude, or personality.
- Training: Keep in mind a fundamental distinction between recognitional knowledge (‘knowing about’) and procedural knowledge (‘knowing how to’). Do not be fooled into thinking that classroom recognitional knowledge will automatically translate into procedural knowledge in the field. Train commanders the way they will be required to function in the field. Realistic training exercises are essential. However, devote considerable effort into enhancing learning from such exercises by providing effective feedback and facilitating reflective self-appraisal of performance.
- Decision support/aiding: Support commanders’ front-end situation assessments rather than back-end decision choices. Help them to understand the situation rather than constrain their choices.
- Monitoring operations: Remember that requiring information from commanders represents a load on their working memory capacity which may degrade the attentional resources they can devote to the immediate task. Be judicious with demands for situation reports and the like!

--In ways such as these, incident commanders’ information processing competencies can be accorded the importance they deserve!

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References

- Adams, R. J. & Ericsson, A. E. (2000). Introduction to the cognitive processes of expert pilots. *Journal of Human Performance in Extreme Environments*, 5(1), 44-62.
- Baddeley, A. D. (2001). Is working memory still working? *American Psychologist*, 56, 851-864.

Holgate, A. (2003). *Decision making processes in effective fireground command and control*. Melbourne, CFA.

McLennan, J., Omodei, M. M., & Wearing, A. J. (1996). The role of prepriming in recognition-primed decision making. *Perceptual and Motor Skills*, 82, 1059-1069.

McLennan, J., Omodei, M. M., & Wearing (2001). Cognitive processes of first-on-scene fire officers in command at emergency incidents as an analogue of small-unit command in peace support operations. In P. Essens, E. Tanercan, & D. Winslow (Eds.), *The human in command: peace support operations* (pp. 312-332). Amsterdam: Mets & Schilt.

McLennan, J., Pavlou, O., & Omodei, M. M. (in press). Cognitive control processes distinguish between better versus poorer decision making by fireground commanders. In H. Montgomery, R. Lipshitz, & B. Brehmer (Eds.), *How professionals make decisions*. Erlbaum.

Omodei, M. M., & Wearing, A. J. (1995) Decision making in complex settings: A theoretical model incorporating motivation, intention, affect, and cognitive performance. *Sprache und Kognition*, 14, 75-90.

Omodei, M. M., Wearing, A. J., McLennan, J., & Clancy, J. (in press). "More is better?" Problems of self-regulation in naturalistic decision making situations. In H. Montgomery, R. Lipshitz, & B. Brehmer (Eds.), *How professionals make decisions*. Erlbaum.

United States Department of Agriculture, Forest Service. (2001). *Thirtymile fire investigation report*. [<http://www.fs.fed.us/rb/wenatchee/fire/Thirtymile-Final-Report.pdf>]

Rasmussen, J. (1983). Skills, rules, and knowledge: Signal, signs, and symbols, and other distinctions in human performance. *IEEE Transactions on Systems, Man, & Cybernetics*, 15, 234-243.

Reason, J. (1990). *Human error*. Cambridge, England: Cambridge University Press.

Table 1

Behavioural Markers of Effective Incident Command^a

Anticipation and Planning

Used 'dead time' to study site plans and diagrams
 Prepared for 'worst case' scenario early, took precautions, called for additional resources
 Warned crews (radio, face-to-face) of likely developments and tasks.

Communication

Used site maps and diagrams to explain intentions to subordinates
 Clear, controlled speech to subordinates
 Maintained eye contact when speaking/listening to subordinates face-to-face
 Radio: paused after subordinate acknowledged call before giving orders/asking questions

Leadership & Assertiveness

Spoke clearly, firmly, decisively (radio, face-to-face)
 Greeted key (role) 'players' (eg, building supervisor) warmly but decisively

Management of Workload

Used white board to record incoming information and to write 'reminder notes'
 Incoming radio traffic: asked sender to "wait" until current task completed
 Requested new arrivals at the Control Centre to wait outside until ready to speak with them
 Gave 'closed' rather than 'open' orders so not required to remember short-term crew assignments

Re-evaluation of Situation

On first indication of deterioration of the situation raised the alarm 'level' so as to call-out more resources

Use of Available Information

Used multiple sources: subordinates, local 'experts', site plans, diagrams

^a From McLennan, Pavlou, & Omodei (in press)

Table 2
Frequency of Cognitive Activity Category^a

	Less Effective Commanders	More Effective Commanders
<i>Situation Assessment/Understanding</i>	32%	38%
<i>Intention Formation/Action Generation</i>	37%	51%
<i>Self Monitoring/Regulation</i>	31% ^b	11%

^a From Mclellan, Pavlou, & Omodei (in press)

^b Mostly 'noting level of overload'

Table 3

Illustrative Extracts From Head-Mounted Video Cued-Recall Protocols^a

Effective Incident Commander:

--Fire (simulated) in a Hospital

“So, at this stage I thought ‘Right, that’s the next thing I have to do is I have to give him (--designated Forward operations Officer--) some manpower for a start so he can start operations’. I wanted to establish early on that he was going to be in charge over there so that’s why I said to him ‘You’re the Operations Officer’. So I could just send him resources and he would delegate the tasks because he had the big picture and he could see what was going on”.

Less Effective Incident Commander:

--Fire (simulated) in an Underground Railway Station

“...at this stage I’ve sort of lost it too because I think I should have gone back and spoken to the Station master and got everyone evacuated through the emergency evacuation system and started smoke ventilation straight away. I wasn’t thinking clearly. I’m focussing on things in general and I’m not clearly identifying tasks and carrying them out. Then confusion reigns because in the short time I’ve let things build up and I haven’t been able to prioritise things. I’ve just let it get away a bit”.

^a From McLennan, Pavlou, & Omodei (in press)