Decision Making and Safety: Problems in predicting fire behaviour

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Abstract
This presentation will discuss a program of research, which investigates how to improve decision making on the fireground. In particular it investigates how training can be used to improve decision making when firefighters are faced with novel situations (adaptive performance).

One of the major dilemmas that trainers face is getting the balance right between theory and practice. Previous research suggests that when dealing with specific problems, trainees learn effectively through examples rather from theoretical knowledge and that individual examples can have a profound effect on performance. When trainees encounter a new problem in the field, they may be able to retrieve a solution from memory, if the features of the current problem resemble those in previous training examples (Rothkopf, Dashen &Teft 2002). However, one of the dangers of this learning strategy is that trainees may focus on the superficial features of an example, rather than the underlying structural aspects of the problem. This is a problem, because it means that trainees can sometimes retrieve an example that is linked with the wrong solution (Allen and Brooks 1991). Two of our studies involving two different fire related tasks (predicting the rate of fire spread, and deciding an appropriate offensive/defensive attack strategy) suggest that this may be a real problem in the fire domain.

The finding that decisions are largely dependant on the retrieval of previously encountered examples has implications for training. It suggests the importance of systematically presenting carefully selected and diverse training examples constructed to promote accurate decisions and reduce erroneous decisions. In addition, appropriate training can improve decision times by reinforcing appropriate links between problems and solutions. Such consistent and frequent reinforcement may short cut the analytic processes involved in decision making and has been shown to produce faster decisions (Rothkopf, Dashen and Teft 2002), which is important in firefighting. This effect, in which analytic processes are by-passed, is supported by models of expertise (Logan 1988) and descriptions of real life decision making in emergency situations (Klein 1997). Experts appear to rely on their wealth of experiences of similar situations rather than undergo a formal process of deliberation.

Our aim is to develop a variety of carefully controlled examples to be used in training to produce fast, accurate and safe decision making. In future studies we hope to test whether simulated training experiences are sufficient to expedite the development of expertise among novices, expertise that traditionally takes decades to acquire. Our earlier studies used static descriptions of incidents as examples. In recent studies we have used case studies in a narrative form offering an economical way of transferring a number of lessons. The case studies provide many rich, contextual details, which can be easily retrieved from memory in later situations. Furthermore, we have found that using examples to illustrate the types of

errors that people can make is particularly effective in enhancing adaptive performance. Findings from the error training study with the NSW Fire Brigade will be presented with examples of materials illustrating the extension of this approach to bushfire.

1.0 Introduction

This collaborative research project examines the most effective method of training fire fighters. The project is funded by the Australian Research Council, and brings together the NSW Fire Brigades, the University of Sydney and The Key Centre for Human Factors and Applied Cognitive Psychology at the University of Queensland. The first phase of the research involved a survey on training and safety issues (Hesketh *et al* 2000) aimed at improving the quality and cost-effectiveness of training in the New South Wales Fire Brigades. Subsequent studies have addressed the best way of combining rules and examples in a training context to maximise adaptability. New approaches to training are needed because of several factors. First, it is no longer possible for trainees to obtain wide experience in a variety of fire contexts, and we need to find ways to speed up the process of developing expertise. Second, the complexity of fire and its unpredictability require adaptive responses on the part of those having to make decisions about methods of attack. Third, the mix of professional and volunteer fire fighters produces additional challenges in command and control decisions, and in training generally. Finally, personnel in fire services are increasingly called upon to deal with a variety of different hazardous situations in addition to fire. These were the practical issues that motivated the research. In addition, the research provided an opportunity to address several substantive theoretical issues about the ways in which trainees make use of prior experiences and examples in future decision-making.

2.0 Aims of the current paper

The decision environment that firefighters face in the field are vastly different to those studied in laboratory based experiments. Firefighting decisions are characterised by time pressure, complexity, uncertainty and ambiguity. Studies of people who frequently make such decisions in real life emergency situations suggest that their decisions are largely dependant on the retrieval of previously encountered examples (see Naturalistic Decision Making approach by Klein 1997a; Klein, Orasanu, Calderwood & Zsambok 1993; and Klein's 1997a Recognition Primed Decision Model). Expert decision makers in crisis situations do not report using rules, analytical strategies, or any other formal methods of analysis, rather they rely on their memories of previous experiences or examples. This finding also holds true in other high pressure settings such as naval surface warfare and marine corps (Klein 1997b) and in medical diagnostics (Norman and Brooks 1997). Expert firefighters tend to assess the situation and arrive quickly at a workable course of action, rather than spend time comparing alternative courses of action and arrive at the optimal choice.

A mechanism by which this may occur has been described by Rothkopf, Dashen and Teft (2002). Given sufficient practice, an association is made between a particular problem and the retrieval of a previously successful solution from memory. Due to the frequency and consistency of this association, analytic processes in which the decision maker evaluates various options in an orderly manner become either simplified or are bypassed and decisions are made more quickly and with very little effort (Logan 1988; Rothkopf, Dashen and Teft 2002). Experts perform well because they have an extensive body of prior experience and examples that they can draw upon and have developed many associations through extensive practice. As well, they have the ability to engage in a 'mental simulation' of events, in order

to make an appropriate decision. What this means in terms of training is that expertise may be best developed through extended practice and exposure to a wide range of examples (Hesketh 1997).

The above discussion highlights the importance of examples in training, and their specific use in developing adaptive expertise. Two other bodies of theory are relevant to optimising training for transfer and adaptability. The first draws on ways in which errors can be used in learning. Specifically, encouraging learning through errors and the use of error examples ensures that the information will be more memorable, highlights the important features that influence the decision, and provides a better basis for challenging incorrect mental models (Ivancic & Hesketh 2000; Hesketh & Ivancic 2002), The second approach emphasises the role of metacognition. Extended practice increases the automation of skills and the speed with which decisions and actions can be executed. However, in unexpected situations, one has to ensure that the automated processes are interrupted, and that some thought is given to unpredictable events. Metacognitive strategies can be used to encourage a trainee to stop and think, monitor their own actions, and regulate their emotions in a situation. For example, in our own research we have used the mnemonic LET to stand for "Learn from your errors", "Expect the unexpected" and "Think before you act", as a metacognitive training strategy to help trainees be alert for the unexpected.

To summarise, we believe that adaptive expertise can be achieved through

- Carefully chosen examples
- Learning by error
- Metacognitive skills

3.0 Using examples to explicate the decision-point

The early studies that we conducted examined the way that people learn to predict the rate of spread of bushfires. The effects of air temperature, wind speed and ground slope on the rate of spread of a fire are extremely complex. Unfortunately, people tend to act as if these relationships are linear, even when they have been warned about the non-linearities involved. For example, they tend to assume that the effect of an increase in wind speed from 30km/h to 40km/h is similar to the effect of an increase from 60km/h to 70km/h. Furthermore, they tend to assume that a 10km/h increase in wind speed has a similar effect on a hot day as it does on a warm day. There have been a number of incidents in which fire fighters have been trapped, because they underestimated how fast a fire would spread under extreme conditions. The aim of these early studies was to assess the best way of overcoming these biases. We presented scenarios of different bushfire situations where the temperature, wind speed, slope etc were varied, and the participants were asked to make judgements about the rate of spread of the fire. During training the participants were exposed to carefully selected combinations of the various fire parameters. Test items involved some of the old values, but also new exemplars. These studies showed that simply giving people more practice does not necessarily improve performance. When we gave trainees new examples with extreme values that fell outside of their range of experience, they still extrapolated linearly, despite being given extensive practice. This meant that they dramatically underestimated the rate of spread on these extreme examples. The data suggest that a better strategy might be to use a relatively small number of highly memorable examples that cover the full range of conditions that trainees are likely to subsequently experience in the field. Our trainees were able to recall the training examples better when there was only a small number of them, and they were well practiced.

If they were able to recall a training example that was relatively close to the example that they were being tested on, then they tended to perform reasonably well. However, if they could not recall a training example, or that example was very different to the test example, then they performed very poorly.

4.0 Rules and Examples: the influence of good and bad analogies.

Studies 2 – 4 examined the extent to which firefighters used prior examples when making decisions about structural fires. Trainees were presented with fire scenarios and decided whether to apply an offensive or defensive strategy, that is, enter a building and fight the fire or not enter the building and prevent fire from spreading to neighbouring buildings. Again, the results suggest that the selection of training examples can have a major impact on subsequent performance. When the trainees saw test examples that were superficially similar to one of the training examples that they have been given, then they tended to make the same decision as they made during training. So, for example, if the training example involved an offensive attack, they were more likely to use an offensive attack for the matching test example. In some cases, this meant that they performed extremely well, because the training example was a "good analogy" to the test example. In other cases, however, they were mislead by the training example, because it was a "bad analogy". The final study in this series examined various methods to enhance the adaptability of trainees. We assessed trainees' ability to recognise exceptional situations in which the procedures that they routinely use do not apply. The findings suggest the best way to train firefighters to recognise exceptions to a general rule may be to present individual examples, which illustrate situations in which the rule does not apply, rather than simply instructing trainees about exceptions to the rule. Collectively, the results from these studies point to the importance of carefully selecting training examples to illustrate the range of conditions that trainees will subsequently experience in the field. One reason why examples may work better than lectures is because they allow the trainees to learn from the errors that they make. This issue was explored in further detail in the next study.

5.0 Examples to cover the different stages in the decision task.

In Study 5, we examined a different fire related task, that is, decision making in incident command. This study compared two training methodologies to examine whether exposure to examples of failure (error training) improves performance and adaptability in fire fighting more than exposure to examples of success (errorless training).

The errors illustrated in this training were primarily related to command, control and communication. Information on real life incidents was collected by interviewing experienced firefighters and from written records such as fire magazines, incident reports and coronial inquest files. Based on these sources, potential areas in which decision errors occurred in incident command were identified. The different types of errors were errors in size up (eg. not obtaining adequate initial information), risk assessment (eg. not taking into account all the hazards within a structure), resources (eg. underestimating the scale of an incident and being caught under-resourced) and procedural errors. Procedural errors illustrated incident commanders who, for example, do not follow procedures on maintaining incident command structure (eg. personality conflicts between senior officers leads to breakdown in chain of command), do not communicate effectively (eg. key information is lost from one commander to the next commander during handover), or do not follow occupational, health and safety guidelines (eg. not wearing personal protective equipment on the fireground).

In order to systematically present these errors, case studies were developed that were based on real fires but manipulated slightly to illustrate the range of issues that firefighters need to deal with during the course of an incident. These case studies were presented as 'war stories' in that they were personalized accounts of fires, told from the point of view of the first responding station officer. This form of presentation was specifically chosen because war stories are thought to be memorable forms of examples that will optimize learning.

6.0 Should examples show mistakes or the correct decision – learning from errors?

In Study 5, two training methodologies were compared and evaluated. These were error training and errorless training. Both these methodologies used war stories as the training medium, in the form of fire case studies. War stories offered an economical way of illustrating a number of learning points. The error training group received case studies that contained errors in fire fighting practices that lead to significant damage, escalation of the fire, injury and sometimes death. In other words, they were exposed to other people's mistakes and, in reviewing them, had a chance to discuss these mistakes and learn from them.

The errorless group, on the other hand, had the same set of case studies as the error group, but due to luck or good management on the part of the incident controller no major problems arose. In these scenarios, damage was minimized, the fire was contained and injuries and deaths were avoided. From the perspective of the storyteller, these were success stories.

Preliminary results suggest that learning from mistakes is more effective than learning from success. This is at odds with the usual practice of teaching from examples of best practice. The results indicate that the error group was able to generate a greater number of viable responses to different fire scenarios than the errorless group (those exposed only to examples of success). This seems to be an indication that the error group are able to think more adaptively since their options for action are greater. Being able to generate more than one course of action is therefore seen as a necessary precursor to adaptive thinking. Compared with the errorless, 'best practice' training group the error group was able to think of more problems in relation to fighting the assessed fire scenarios and therefore seem to be reflecting more critically on the procedures used in fire fighting. As well, those exposed to other people's failures in the error training group took on board these mistakes when commenting on the management of the fires on which they were tested. Many of the things that went wrong in earlier scenarios were repeated as things to be vigilant about in the following scenarios. This indicates that the error case studies are building expertise.

We think error training is effective because it provides a fast track to adaptable experience. Errors are salient and memorable and allow fire fighters to reflect on other people's mistakes in order to increase their conceptualization of the best way to fight each fire they encounter. In this way errors help to build accurate mental models. Error training may delay the routine application and automation of skills and make trainees think more carefully, thus helping trainees to avoid mistakes in the future. By storing similar past errors in memory and the cues that predict failure, individuals can prevent the repetition of past mistakes.

7.0 Training using simulated experiences.

In addition to the benefit of optimising transfer of knowledge from the training context back to the workplace, simulation provides a way of safely increasing both practical experience

and levels of complexity. Klein (1997b) promotes simulation as a way of building up an experience bank as one of several primary methods for achieving expertise. Indeed, in the initial training and safety survey conducted by this group, respondents, regardless of rank "indicated a strong desire for a greater practical component in training and the use of variety in training, including scenario-based training, CD ROM's and simulation" (Hesketh *et al.* 2000, p. 10). Moreover, station officers reported that recruits lacked basic operational skills that could be improved through more practical activities. Simulation provides the opportunity for increased practical skills at no risk to the recruit. The use of simulators therefore can be seen as helping to supplement the practical components of training.

Simulation activities vary in their degree of realism, ranging from low quality, low cost, low fidelity tactical decision games to high quality high fidelity, expensive immersive simulation systems such as the type typically used in training air pilots. There has been evidence to suggest that even the bottom end of the spectrum, low fidelity simulations are effective in improving decision making, heightening situational awareness and clarifying roles (Crichton & Rattray 2002). The Vector fire interactive simulator recently adopted by the NSW Fire Brigade lies somewhere in the middle of this quality continuum with a simulation that is not high in fidelity, nor truly immersive, but which strongly utilizes actual job features.

In projects currently underway, we are developing a method of using Vector to allow trainees to learn from errors in a relatively safe, simulated environment. Given a fixed scenario, participants observe an actor in the role of Incident Commander, who commits various errors while deploying resources to fight the fire and rescue casualties. The consequences of these errors are illustrated and discussed after the incident. During the debrief, trainees are shown a 3D replay of the incident and in conjunction to this, they listen to an internal monologue in which the incident commander recalls their actions in a step by step fashion. In this way, trainees can "step into the shoes" of the narrator and gain an understanding of how a lack of understanding or judgement or loss of situation awareness led the incident commander to act inappropriately.

8.0 Recommendations for practice

The research has several important implications for training. Trainees should be presented with a series of practice examples illustrating the range of different conditions that they may subsequently encounter in the field. These examples should include unusual situations, requiring adaptability.

Trainees should also be encouraged to think about errors and to learn from them. Even the more experienced trainees should be given the opportunity to make errors. If errors are re-framed in a positive way, as opportunities to learn, rather than as a way of putting people down, it may lead to better learning and better confidence in abilities.

In conjunction with the error training, routine procedures should be trained to the point of automation where no thought is required, so that mental resources can be employed in thinking adaptively about important features of the fireground and relevant problem solving.

Training should also facilitate the discussion of 'war stories' about fires where things have gone wrong or there have been near misses. These are a good way to encourage members think about other people's errors and to learn from them. Conducting debriefs following incident responses is another way of encouraging a culture of critical thinking and

adaptability. These debrief should not only discuss successes but also failures and near misses.

Finally, encouraging the use of metacognitive strategies to evaluate one's own performance and regulate emotions may be useful in attaining peak performance.

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