Eliciting experts' knowledge in emergency response organizations

Journal:	*International Journal of Emergency Services*
Manuscript ID:	IJES-06-2014-0009.R2
Manuscript Type:	Research Paper
Keywords:	Expertise, Tacit Knowledge, Decision making, Firefighters, Critical decsiion method, Training

ELICITING EXPERTS' KNOWLEDGE IN EMERGENCY RESPONSE ORGANIZATIONS

Abstract

Purpose: Experienced fire ground commanders are known to make decisions in time-pressured and dynamic environments**.** The purpose of this paper is to report some of the tacit knowledge and skills expert firefighters use in performing complex fire ground tasks.

Design/Methodology/Approach: This study utilized a structured knowledge elicitation tool, known as the critical decision method (CDM), to elicit expert knowledge. Seventeen experienced fire-fighters were interviewed in-depth using a semi-structured CDM interview protocol. The CDM protocol was analyzed using the emergent themes analysis (ETA) approach

Findings: Findings from the CDM protocol reveal both the salient cues sought, which we termed critical cue inventory (CCI), and the goals pursued by the fire ground commanders at each decision point. The CCI is categorized into five classes based on the type of information each cue generates to the incident commanders

Practical Implications: Since the critical decision method is a useful tool for identifying training needs, this study discussed the practical implications for transferring experts' knowledge to novice firefighters

Originality/Value: Although many authors recognize that experts perform exceptionally well in their domains of practice, the difficulty still lies in getting a structured method for unmasking experts' tacit knowledge. This paper is therefore relevant as it presents useful findings following a naturalistic knowledge elicitation study that was conducted across different fire stations in the UK and Nigeria.

Keywords: Expert, Tacit knowledge, Decision making, critical decision method, firefighters, experience, cues, emergency response, training

Article classification: Research paper

Introduction

During fire incidents, civilians whose lives and properties are at stake usually expect a lot from the incident command teams (Boin and Lagadec, 2000). In fact, members of the public usually judge the effectiveness of any response effort on the basis of how much lives and properties response crews were able to successfully save (Tissington and Flin, 2005; Ingham, 2008). Therefore considering the huge expectations members of the public hold for response teams, it is logical to expect that managing more dangerous and un-predictable fires will call for the skills and knowledge of the more experienced firefighters.

Cognitive researchers have broadly classified experts' knowledge into two broad categories i.e. explicit knowledge and tacit knowledge (Ten Berge and Van Hezewijk 1999; Van Merrienboer *et al.*, 2002; Tulving, 2002). Explicit knowledge is the type of knowledge that is easily expressed verbally by professionals, and it is made up of stored facts and events which experts are able to state explicitly. This type of knowledge supports performance through the conceptual understanding of the procedures and principles surrounding job tasks in a particular domain. Experts have been shown to possess extensive explicit knowledge which is subsequently represented in schemas (Salas *et al.*, 2010), and it is this schema-based framework that enables experts to retain and recall information with a high degree of accuracy (Ericsson *et al.*, 2007).

Nonetheless, despite the importance of acquiring declarative knowledge, it has proved to be of limited use in the area of generating effective skilled performance or for subsequent use for training purposes (Klein, 1997; Clark *et al.*, 2007; Okoli *et al.*, 2013). This is because experts can unintentionally misrepresent the conceptual knowledge upon which their competence is based: a paradox where professionals are able to refer to scientific data, theoretical manuals and standard operational procedures (SOPs) in clear explicit terms, yet using the same factual knowledge *tacitly* (Eraut, 2004; Fessey, 2002; Spender, 2008; Feldon, 2007). On this note, it therefore seems that experts' performance is qualified by another type of knowledge i.e. tacit knowledge (Nonaka and Krogh, 2009). Tacit knowledge operates outside the conscious awareness of professionals and basically involves a detailed understanding of how a system operates (how to do things). This knowledge has been regarded as a compulsory requirement for all skilled performance and is characterized by both situational and strategic procedural qualities such as assessing, deciding, acting and monitoring (Polanyi, 1962; Alavis and Leidner, 2001; Eraut, 2004).

There has been a long standing debate in the literature over the validity of some methods that have previously been used to elicit experts' knowledge e.g. laboratory experiments, simulation tasks, quantitative survey etc. (Doherty, 1993; Bontis, 2001; Kahneman and Klein, 2009; Dane and Pratt, 2009). Although these previous methods served their purposes to certain extents, sceptics still believe they are incapable of effectively capturing tacit knowledge (Lipshitz *et al.*, 2001; Tsoukas, 2003; Klein, 2008; Nonaka and Krogh, 2009). This is mainly because tacit knowledge dwells within the unconscious realm, hence requiring a more structured knowledge elicitation tool in order to make any meaningful contribution.

This paper therefore sets out to address three critical issues associated with the elicitation of expert knowledge and/or the transfer of such knowledge: (i) it assesses the importance of utilizing only the most qualified personnel (verified experts) when eliciting knowledge for training purposes, especially in high risk organizations such as the fire service (ii) it discusses one of the most effective strategies for eliciting expert knowledge ─ the critical decision method and (iii) it discusses the implications of transferring tacit knowledge from experts to novices.

In doing so, the naturalistic decision making approach, and in particular the critical decision method, was employed in this study as the knowledge elicitation tool. According to Klein (2008), naturalistic decision making is a descriptive model which gives a detailed representation of how experts actually make decisions in the real world, using their experience. This contrasts the normative model or classical theory which suggests, in advance, how decisions should be made e.g. using mathematical formulas or rules (Satz and Ferejohn, 1994).

We wish to clarify that although this study was carried out in two different countries, UK and Nigeria, the findings reported here represent the elicited tacit knowledge that is applicable to expert firefighters in both countries. The cultural and cognitive differences observed amongst the firefighters from both countries are beyond the scope of this current article and are therefore not reported here**.**

Why do we need experts in Knowledge Elicitation?

Many authors are generally convinced that emergency frontline responders need both a new way of thinking and a different approach to training — if they are to be better equipped for the challenges posed by the modern day crises (Boin and Lagadec 2000; Alexander 2000; Salas *et al*., 2010; Milasinovic *et al*., 2010). The training methodologies currently being adopted by most emergency organizations and the knowledge and routine skills derived from such 'normal' training have been shown to no longer be sufficient for coping with the complexity and unpredictability associated with present day crises (Boin and Lagadec, 2000; Ericsson *et al*., 2007). This also explains why the field of emergency and crisis management, in times like this, need more studies that will focus on demystifying the experiences, knowledge (especially tacit knowledge) and skills (including non-technical skills) of experts (Flin *et al*., 2008)

But who is an expert? Two very useful definitions have been selected for the purpose of this study: (i) Shanteau (1992) defined experts as “those who have been recognized within their profession as having the necessary skills and abilities to perform at the highest level”. (ii) Kahneman and Klein (2009), using an analogy within the domain of fire-fighting, assert that “when colleagues say: if Person X had been there instead of Person Y, the fire would not have spread as far,” then Person X is regarded as an expert in that organization. The first definition therefore relates to personal competence while the second links expertise to peer nomination.

What are the qualities that make experts outstanding in their domain of practice?

Summarized below are some specialized techniques used by experts for solving difficult domain tasks and making intuitive decisions in time pressured environments:

- *Information filtering***.** Experts are able to systematically sift relevant information from irrelevant ones thereby increasing the cognitive capacity of working memory in order to accommodate more useful data. This technique has also been shown to drastically reduce the risk of cognitive overload in experts (Tulving, 2002). Experts organize their schemata such that they are able to ignore *mental noise*, which allows them pay closer attention to the more pressing cognitive demands (Klein, 2003)
- *Rich knowledge base and mental models.* Experts have been shown to possess greater domain knowledge than novices (Kahneman and Klein, 2009). This is because experts strive to organize their knowledge using inferences and principles which, in turn, allows them to construct a rich mental model (Van Merrienboer *et al*., 2002). A Mental model is a cognitive representation of how things work or an internal representation of the external world. In addition, experts tend to understand the dynamics of events in their domain and know how tasks and subtasks are supposed to be performed, how equipment is supposed to function, and how team members are supposed to perform their tasks (Ingham, 2008).
- *Pattern matching:* This is the ability of experts to address a current situation by recognizing patterns as similar to those previously stored in memory (Gobet 2005). This particular feature has elsewhere been termed recognition primed decision making (Klein, 1997). Furthermore, experts tend to identify cues collectively (patterns), whereas novices

focus more on fragmented cues without having much understanding of how cues actually link up to form a whole.

- *Finding leverage points:* This is the ability of experts to form effective improvisation strategies when faced with novel (atypical) situations that require making creative decisions. For example, Klein (1997) reported how a fire-ground commander used a belt intended to secure firefighters while on a ladder to rescue a woman who was dangling on the metal support of a highway sign. The report showed that the commander had mentally simulated a series of tactics that will ensure the woman was successfully rescued and eventually determined that the ladder belt would do the trick better. Ericsson *et al* (2007) purport that experts are able to develop workable improvisation strategies because they spend relatively more time analyzing a situation than the time they spend deliberating on a course of action.

- *Mental simulation:* This is the ability of experts to project the environment's current status into the future. Once an option is generated, experts use mental simulation to work it through at a deeper level, looking for pitfalls and/or opportunities ─ a process also known as *progressive deepening* (Kahneman and Klein, 2009). Thus, the accuracy of mental simulation is hinged on the quality of one's mental model. As Salas *et al* (2010) put it: mental simulation is simply "running a mental model".

Methods

Knowledge elicitation using the critical decision method

Some emergency services organizations such as fire-fighting heavily rely on experts' explanations about the cognitive strategies they use in solving difficult problems, which are subsequently used as the basis for developing training instructions for junior officers (Clark *et al*., 2007; Hannabuss, 2000; Feldon, 2007; Wong, 2000). Knowledge elicitation in such domains is therefore a crucial aspect of organizational learning. However, designing training instructions in such knowledge intensive organizations can only be possible when unconscious skills have been made conscious and when tacit knowledge has been transformed to explicit knowledge (Hannabuss, 2000; Alavi and Leidner, 2001; Spender, 2008; Nonaka and Von Krogh, 2009).

Previous studies have shown that when structured knowledge elicitation techniques are not used in the elicitation process, most of the freely recalled self-reports from experts are often incomplete, inaccurate or error-prone (Eraut, 2004; Cooke and Breedin, 1994). Furthermore, the need for a structured knowledge elicitation method stems from the fact that experts are not fully aware of about 70% of their own decisions and mental analysis of tasks and so are unable to fully account for their judgments in retrospect (Clark *et al.,* 2007). This obviously has serious implications for knowledge management since expert knowledge is undoubtedly required in supporting the design of a training curriculum.

In this regard, the critical decision method has proved effective in enhancing the process of knowledge elicitation across a wide range of domains (see Hoffman *et al*., 1998 for a review). Klein *et al* (1989) described the critical decision method as a retrospective interview strategy that applies a set of cognitive probes to actual non-routine incidents that required expert judgment or decision making. CDM is designed to focus on the cognitive strategies that aided the successful management of past incidents, which is then used to articulate the training needs for managing future incidents.

Participants

The sample size for this study is comprised of seventeen experienced fire-fighters (n=17) and was selected across different major fire stations in the UK and Nigeria. Since it was important to ensure that the participants' level of experience was verified and not assumed, participants were carefully selected on the basis of their rank/position and also through peer nomination (Shanteau, 1992). All the participants interviewed in this study had personally been involved in managing real-life fire incidents, which implies making a series of decisions independently. Also, the interviewed participants had at least operated as incident or operational commander (i.e. managing crews and leading one or more fire engines). Participants who had neither received incident command training nor managed a complex high-risk fire incident were therefore excluded from participating in the study. Overall, the mean year of experience for all the seventeen participants was 17.56

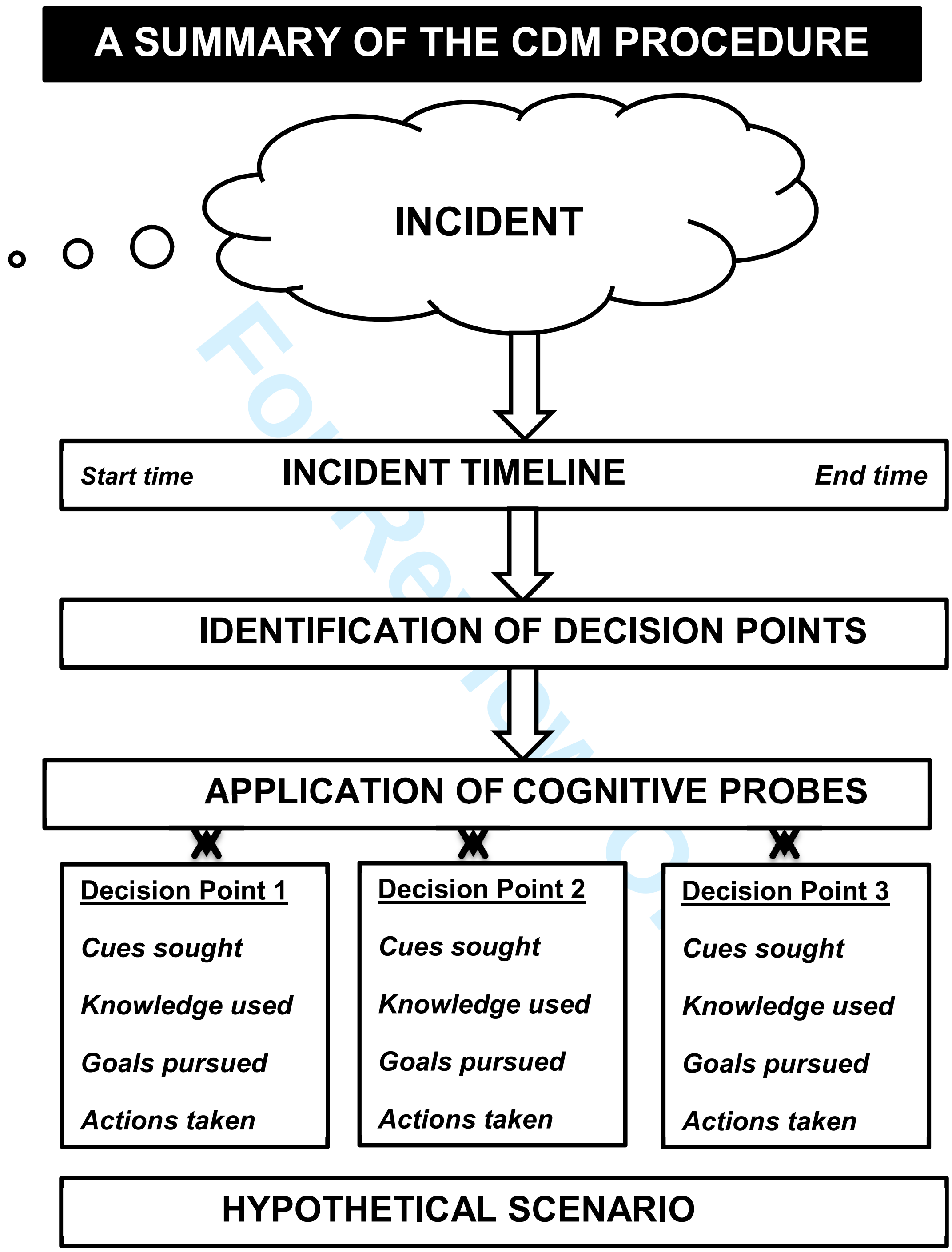
Procedure

Participants were first asked to recall and 'walk-through' a remarkable as well as a memorable major fire incident, which particularly challenged their expertise. They were advised in advance, either through email or phone call on the nature of the interview, and were also advised on the type of incidents that was of interest to the researcher i.e. non-routine incidents. The reason for focusing on non-routine incidents is because experts tend to use their tacit knowledge mostly when solving difficult tasks than they do when performing routine tasks (Polanyi, 1962).

After narrating the incident from start to finish (see Figure 1), participants were asked to go over the incident a second time, this time with the intention of constructing a timeline (i.e. summarizing key decisions that were made from the start of the incident to when the incident was brought under control). During the timeline construction, decision points were identified (see Figure 1). A decision point is the basic unit of analysis in this study and is defined as the point where a specific course of action was chosen from several other potentially available alternatives. Examples of decision points reported by experts include: *'I committed my crews with breathing apparatus into the building', 'I withdrew my crews from the building because it was too risky', 'I requested more appliances because I thought we didn't have enough at that moment'*. The timeline construction and decision point identification phases were then followed by applying a set of cognitive probes so as to better elicit the basis of experts' decision making strategies. The CDM cognitive probes contain a series of semi-structured interview questions such as the rules being followed, knowledge being used and how, training utilized, cues sought, goals pursued at each decision point etc. (see Klein *et al*., 1989; Hoffman *et al*., 1998 for details on the CDM procedure).

Each interview lasted between 1hr-2hr and was tape recorded with the consent of each participant, and a total of 70 decision points were obtained from the seventeen interviews. The interviews were transcribed verbatim and analysed using a combination of qualitative coding process and emergent themes analytical method that was developed by Wong (2004).

Figure 1: A visual description of the phases involved in the CDM procedure, Adapted from Klein *et al.*, 1989



Results, findings and Discussion

Due to space constraints, we discuss only two components of experts' tacit knowledge from the CDM protocol: (i) The cues experts seek at each decision point and (ii) the goals they pursue at each decision point.

Cues

This study identifies the importance of cues and explains the roles different cues play in enhancing decision making on the fire ground. Wong (2004) defined a cue as "any stimuli with implications for action", and this definition has been adopted in this study. Cues therefore include smoke colour, fire intensity, nature of substances present in buildings etc.

It is worthy of note that the cues present in an environment must be able to generate useful information to the decision maker, who then interprets, processes and translates the derived knowledge into a workable course of action. In other words, attaining effective performance might be hugely jeopardized if essential cues are not recognized by the actor in a timely manner. In this study, we identified 34 different cues across the seventeen incidents. These cues were then further categorized into five classes depending on the specific type of information they convey to the incident commanders (Table 1). For example, safety cues are cues that suggest the most appropriate safety boundaries for the crews and the members of public. These safety cues guide subsequent safety actions and also determine if some level of risks could still be accepted or if it is safer to be more precautionary. Environmental based cues (e.g. wind movement or atmospheric temperature) on the other hand refer to the climatic cues that are external to the incident, which allows commanders to make sense of how task performance could be affected.

Table 1: list of cues that aids experts' decision making

Critical Cue Inventory (CCI)

1. **Safety related Cues**
   - Cracked wall
   - Collapsed wall
   - Roof stability
   - Nature of burning contents or class of fire involved (e.g. metal fire, gas fire, batteries, acetylene)
   - Substances likely to be present in the building (e.g. petrol or other combustible materials, cylinders)
   - Potential for spread of fire
   - The behaviour of smoke in the building (potential for a flashover or backdraft)
2. **Cues that indicates the "Nature of Problem"**
   - Size of Fire
   - Intensity of fire blaze
   - Movement pattern of the flame
   - Egress of flames (through the windows, attics, doors)
   - Colour of smoke (yellowish rainbow, blue, thick black)
   - Smell/odour of smoke and burning substances
   - Texture of smoke (thick, light, cloudy)
   - Proximity of the fire to other buildings
   - The severity of physical damages caused
   - The extent of injury to victims
   - Room temperature
   - The class of fire involved (class A-F)
3. **Environmental-based Cues**
   - Wind direction
   - Wind velocity/intensity
   - External temperature (Hot, warm, harmattan, cold)
   - Catchment area (Residential, Factory, Industrial, Rural, City centre)
   - Location of incident (Rural or Urban area)
4. **Affective and Behavioural cues (cues that are derived from people's emotional reaction to the incident)**
   - Verbal threats from victims (abusive words, arson)
   - The number of crowds shouting "help"
   - The level of panic observed in the crowd
   - The intensity of cry and wailings from trapped victims
   - The numbers of passers-by/crowd gathered at the scene of the incident
5. **Search and Rescue (cues that influence officers' risk taking behavior to rescue victims or save properties)**
   - The location of unaffected properties
   - The location of the seat of fire
   - The type of building involved (terraced, block of flats, single-story, multi-storied)
   - The position of the entry points (easily accessible or obstructive)
   - The category of victims trapped (elderly, disabled, mentally challenged)

The above findings show that it is not just enough to identify cues on the fire ground; experts must also be able to make sense of those cues, interpret their meaning and determine how such cues are likely to affect task performance. For example, it is almost useless for incident commanders to spot a cracked wall or a collapsed roof if they are, in turn, not able to infer the implications of such cues and act accordingly.

These findings seem to contradict the early work of Easterbrook (1959). Easterbrook's cue-utilization theory suggests that consistently arousing the emotions of decision makers through some external stimuli will result in the reduction in the number of cues that will eventually be generated and utilized by the decision maker. The theory also suggests that such reduction in the number of generated cues usually have negative impacts on task performance. This current study however found little or no evidence to support Easterbrook's theory. The expert firefighters were not found to be distracted away from identifying other cues, even for incidents where victims and passers-by were reportedly being very emotional (crying, shouting, wailing etc.). As a result, this study is seen to favour the position of other scholars who believe that generating more or less cues does not necessarily result to a better performance (Tissington and Flin, 2005; Perry and Wiggins, 2008). According to these scholars, what matters most is that the decision maker is able to understand the most relevant cues needed to generate action plans (IF-THEN, WHEN-THEN relationships), including an understanding of the implications of the identified cues

Findings from Table 1 also show that experts are able to easily discriminate between cues, and this seems to be possible because of their well refined perceptual skills developed over many years of consistent practice (Gobet, 2005; Ericsson *et al*., 2007). Cue discrimination relates to one's ability to identify subtle differences and/or similarities across various informational cues. For example, experts are expected to have an understanding of the various classes of fire that exist and be able to discriminate between them. These include using visible cues such as smoke colour/ texture, and perceptual cues such as smell/odour as discriminatory variables. This is why cue discrimination has also been regarded as one of the hallmarks of expertise (Gobet, 2005; Perry and Wiggins, 2008). For example, in an empirical study aimed at identifying the rules used by experts to differentiate roof "squishiness", Calderwood *et al.* (1987) surprisingly discovered that no visible rule exists for such a decision. One of the experienced fire-fighters interviewed by the authors explained that "you simply have to stand on a number of squishy roofs and on a number of un-squishy roofs until you are able to know the difference between them. Unfortunately, to most novices all roofs are squishy".

Goals pursued

One of the benefits of using the critical decision method for knowledge elicitation is that it is designed, *inter alia*, to capture the main goals and sub-goals pursued by experts at each decision point. True experts are goal-oriented individuals who have specific goals and expectations in mind. Analysis of the CDM data showed that all the experts were pursuing at least one goal at each decision point (Table 2).

In the CDM protocol, participants were asked to explain the goals they were pursuing at each decision point, after which the goals were carefully matched against the incident account for verification (Figure 1). Also, since the incident commanders will normally pursue different goals depending on the circumstances surrounding their respective incidents, they were further asked to explain the rationale behind the goals and sub-goals they were pursuing at each decision point. The goals pursued by expert commanders were analyzed across all the incidents and then sub-categorized as shown in Table 2:

Table2: Analysis of Goals pursued by experts and the number of decision points associated with each goal.

Goals pursued	**No of Decision points**
Safety of crew and public members	19
Resource reinforcement and support	8
Timely completion of task	7
Crew-task management	5
Ventilation of building	2
Prevention	15
Rescue & Salvage	4
Extinguishing the fire	13
Evacuation	3
Gaining access to the scene of the fire	8
Professionalism & Ethics of work (PEW)	10

Table 2 shows that the main goal for all response operations on the fire ground is not necessarily to extinguish the fire, rather response goals seem to vary depending on certain factors such as the nature of the incident, the environment where the incident occurred, the make-up of the response team as well as the intensity and size of the fire. Therefore, the popular assumption that fire commanders mainly pursue the goal of “extinguishing the fire” tends to oversimplify the complexity of fire ground tasks in real life. For instance, in high-risk incidents such as incidents involving highly combustible substances in buildings with access difficulties, incident commanders were found to be more concerned with ensuring the safety of both the crew and those of the members of public. In such situations, their main goal seemed to be safety related (DP=19), but at the same time doing their best to extinguish the fire with the resources available at their disposal. Conversely, in incidents where the fire is well-alight and rapidly blazing, incident commanders tended to aim at either damage limitation/containment, in which case they focus on “boxing” the fire, or prevention, in which case they attempt to avert the fire from spreading to other surrounding buildings or properties.

The above insights are therefore consistent with existing claims that the ability to manage shifting goals under time pressure is one of the hallmarks of expertise (Shanteau, 1992; Klein, 1997; Wong, 2000). A direct relationship exists between the cues identified by experts, the goals they pursue and the subsequent actions they take. In other words, as soon as experts identify certain cues, they use their experience and wide domain knowledge to interpret the implications of such cues and then prioritize response goals. This implies that goals are rarely set from the start of the incident since the goal(s) pursued at any given time is dependent on the ever changing conditions of the incident. But once the fire ground commanders eventually set their goals and sub-goals, they are then ready to channel their resources towards the attainment of such goals, however with some degree of flexibility in order to accommodate potential changes.

The above findings give credence to the descriptive decision making theory proposed by Beach (1978, 1993), known as the image theory. The theory postulates that decision makers usually represent information in the form of four images: a set of values and beliefs, the specific goals to which the decision maker is striving, the defined operational plans for reaching the goals, and the anticipated results of the plans. Beach (1993) advised that for tasks to be carried out effectively, these four images must be well harnessed by the decision maker such that conflicts are avoided between and within the four images. The author puts it this way: “Each plan is an abstract sequence of potential activities beginning with goal adoption and ending with goal attainment”. This implies that no action plan is developed independent of the goal it aims to achieve.

Conclusion

With the emergence of expert systems and growing interest in naturalistic/real world decision making, researchers have become interested in the *content* knowledge of experts (Shanteau, 1992; Hoffman et al., 1998). As shown from earlier discussions, one of the most effective ways of improving the overall level of human performance in a particular task is to understand how proficient individuals actually perform such task in real life (Okoli *et al*., 2013). The principle behind this approach is that by carrying out a detailed study on the general knowledge, specific information, and reasoning processes used by experts, a "model" which exhibits some of the properties of the expert can be developed.

However, eliciting expert knowledge is not enough if such knowledge is not intended to be effectively utilized for training purposes. In other words, one of the very important conditions for developing the cognitive skills of less experienced personnel is by providing them with adequate opportunities to learn the relevant cues used by the most qualified domain experts (Ericcson *et al*., 2007). This supports Winterton *et al*.'s (2005) definition of knowledge as the interaction between intelligence (capacity to learn) and situation (opportunity to learn). Thus, without an opportunity to learn and practice, people will be unable to update their knowledge banks.

Facilitators and instructional design theorists must therefore be able to meet the challenges of designing and implementing well-structured programs that will aim to provide learners with a focused, yet extensive index of experiential (tacit) knowledge over a given period of time (Klein, 2003). Through such training and the lessons learnt from it, the schemata (action scripts, repertoires and mental models) of less experienced personnel can then be developed until they are able acquire the skills required for performing non-recurrent tasks (Van Merrienboer *et al*., 2002; Feldon, 2007; Ericsson *et al*., 2007).

Hence, in terms of knowledge transfer, we strongly recommend the concept of *learning through practice* as a useful means for teaching novices most of experts' skills. We suggest that junior officers, in addition to the theoretical lessons they are made to learn, should also be allowed to have real-life practical experiences by attending real fires under the tutelage of the more experienced officers. There is substantial evidence to demonstrate that experiences gained in real-life (on-the-job) practice settings have the potential of making more important contributions that cannot be afforded by experiences in other settings (c/f Klein, 2003). Learning should therefore be seen as an ongoing activity for less-experienced personnel as well as a crucial part of their daily thinking and acting

(Fessey, 2002). This way, novices are made to learn the most current, tailored and up-to-date skills based on the constantly changing environment typical of most high risk organizations. In sum, novice firefighters can learn from more superior officers by consciously learning and practicing what the superior officers do. Observing and practicing what others does can be a fast way of understanding how various components of a complex task fit together to form a whole task. What learners see continuously over a period of time automatically creates a mental "picture" which is then structured in their memory and ready to be recalled when similar challenges are encountered in the future.

Finally, although we acknowledge the decreasing rate of major fire incidents, particularly in the UK, implying that novices might not have as many windows of opportunity of gaining real-life experience(s) as would normally be expected, we still believe, nonetheless, that the outputs presented in this article (the critical cue inventory and goal decomposition) could play a significant role in enhancing the learning of complex skills through the design of training and simulation exercises. For example, training facilitators can construct a wide range of learning tasks from the elicited expert knowledge, with the hope of making existing training curricula more realistic and more representative of real-life incidents. This will also ensure that the intuitive skills required for managing real life incidents in dynamic and time-pressured conditions are made available to novices especially when they do not have the immediate opportunity of gaining such experience(s) in real-life.

Further studies are therefore needed in the area of structuring training curricula that will both be effective and at the same time considerate for the less experienced firefighters. By being considerate we mean a learning framework that will strive to attain a balance between the cognitive load within the learning materials (intrinsic cognitive load) and the cognitive capacity of the learners.

References

Alavi, M. and Leidner, D. E. (2001), "Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues", *MIS Quarterly*, Vol 25 No.1, pp. 107-136.

Alexander, D. (2000), "Scenario methodology for teaching principles of emergency management", *Journal of Disaster Prevention and Management,* Vol. 9 No. 2, pp. 89-97.

Boin R. A. and Lagadec P. (2000), "Preparing for the Future: Critical Challenges in Crisis Management", *Journal of Contingencies and Crisis Management,* Vol. 8 No. 4, pp. 185–191.

Bontis, N. (2001) "Assessing knowledge assets: a review of the models used to measure intellectual capital", *International Journal of Management Reviews*, Vol. 3 No. 1, pp. 41-60.

Calderwood, R., Crandall B. and Klein G.A. (1987), "Expert and novice fire ground command decisions" (KATR-858(D)-87-02F). *In Final Report under contract MDA903-85-C-0327 for the U.S.* Army Research Institute Alexandria, VA Fairborn OH, Klein Associates.

Clark, R. E., Feldon, D., van Merrienboer, J., Yates, K. and Early, S. (2007), Cognitive Task Analysis, in Spector, J. M., Merrill, M. D., van Merriënboer, J. J. G. and Driscoll, M. P. (eds.) *Handbook of research on educational communications and technology*, Lawrence Erlbaum Associates, Marwah NJ.

Cooke N. J. and Breedin S.D. (1994), "Constructing naive theories of motion on-the-fly", *Memory and Cognition,* Vol. 22, pp. 474-493.

Dane, E. and Pratt, M.E. (2009), "Conceptualizing and measuring intuition: a review of recent trends", *International Review of Industrial and Organizational Psychology*, Vol. 24, pp. 1-40

Doherty, M. E. (1993), "A Laboratory Scientist's View of Naturalistic Decision Making", in G. Klein, J. Orasanu, R. Calderwood and C. Zsambok (eds) *Decision Making in Action* pp, Ablex, Norwood CT, pp.362-388

Easterbrook, J. A. (1959), "The effect of emotion on cue utilization and the organization of behavior", *Psychological review,* Vol. 66 No. 3, pp. 183-201

Eraut, M. (2004), "Informal learning in the workplace", *Studies in Continuing Education*, Vol. 26 No 2, pp. 247-273

Ericsson, K. A., Prietula, M. J. and Cokely, E. T. (2007), "The making of an expert", *Harvard Business Review,* Vol. 85, pp. 114–121

Feldon, D.F. (2007), "The Implications of Research on Expertise for Curriculum and Pedagogy", *Journal of Education Psychology Review*, Vol. 19, pp. 91-110

Fessey, C.A. (2002), "Capturing expertise in the development of practice: Methodology and approaches", *Learning in Health and Social Care*, Vol. 1 No.1, pp. 47-58.

Flin, R., O'connor, P. and Crichton, M. (2008), *Safety at the sharp end: a guide to non-technical skills*, Ashgate, UK

Gobet, F. (2005), "Chunking models of expertise: Implications for education", *Applied Cognitive Psychology,* Vol. 19 No.2, pp.183-204.

Hannabuss, S. (2000), "Narrative Knowledge: eliciting organizational knowledge from storytelling", *Aslib proceedings*, Vol. 52 No.10, pp. 402-413

Hoffman, R.R., Crandall, B. and Shadbolt, N.R. (1998), "Use of the Critical Decision Method to elicit expert knowledge: A case study in the Methodology of Cognitive Task Analysis", *Journal of Human Factors and Ergonomics Society,* Vol. 40 No.2, pp. 254-276

Ingham, V. (2008), "Crisis communication and multimodal decision making on the fireground", *Australian Journal of Emergency Management,* Vol. 23 No. 3, pp. 9-13

Kahneman, D. and Klein, G. (2009), "Conditions for Intuitive Expertise; A failure to Disagree", *Journal of the American Psychological Association* Vol. 64, No. 6, pp. 515-526

Klein, G. A., Calderwood, R. and MacGregor, D. (1989), "Critical decision method for eliciting knowledge", *IEEE Transactions on Systems, Man, and Cybernetics,* Vol. 19, pp. 462-472.

Klein, G. (1997), "Developing expertise in decision-making", *Thinking and Reasoning, Vol. 3*, pp. 337-352.

Klein, G. (2003), *The power of Intuition: How to use your gut feelings to make better decisions at Work*, Doubleday, New York.

Klein, G. (2008), "Naturalistic decision making", *The Journal of the Human Factors and Ergonomics Society*, Vol. *50 No.* 3, pp. 456-460.

Lipshitz, R., Klein, G., Orasanu, J. and Salas, E. (2001), "Focus article: Taking stock of Naturalistic Decision Making", *Journal of Behavioural Decision Making,* Vol. 14, pp. 331-352

Milasinovic S, Kesetovic Z. and Nadic, D. (2010), "The power and impotence of crisis management in facing modern crises", *Scientific review paper,* Vol. 7, No. 2, pp. 273-290

Nonaka, I. and Von Krogh, G. (2009), "Perspective—Tacit knowledge and knowledge conversion: Controversy and advancement in organizational knowledge creation theory", *Organization science*, Vol. 20 No. 3, pp. 635-652.

Okoli, J.O., Weller, G., Watt, J. and Wong, B.L.W. (2013), Decision making strategies used by experts and the potential for training intuitive skills: A preliminary study, in *Proceedings of the 11th International Conference on Naturalistic Decision Making, May 22-24,* Arpege Science Publishing, Marseille.

Polanyi, M. (1962), "Tacit knowing: Its bearing on some problems of Philosophy", *Reviews of Modern Physics*, Vol. 34 No. 4, pp. 601-615.

Salas, E., Rosen, M. A. and DiazGranados, D. (2010), "Expertise-based intuition and decision making in organizations", *Journal of Management,* Vol. 36 No. 4, pp. 941–973.

Satz, D. and Ferejohn, J. (1994), "Rational choice and social theory", *The Journal of philosophy*, Vol. 91 No. 2, pp. 71-87.

Shanteau, J. (1992), “Competence in experts: the role of task characteristics”, *Organisational Behaviour and Human Decision Processes,* Vol. 53, pp. 252-266.
Spender, J.C. (2008), “Organizational learning and knowledge management: Whence and whither?”, *Management Learning,* Vol.39 No. 2, pp. 159–176.
Ten Berge, T. and Van Hezewijk, R. (1999), “Procedural and Declarative Knowledge: An Evolutionary Perspective”, *Theory and Psychology*, Vol. 9 No. 5, pp. 605–24.
Tissington, P. and Flin, R. (2005), “Assessing risk in dynamic situations: lessons from fire service operations”, *Risk Management*, Vol. 7 No. 4, pp. 43-51.
Tsoukas, H. (2003), “Do we really understand tacit knowledge?”, in M. Easterby-Smith, M. Lyles (eds), *The Blackwell Handbook of Organizational Learning and Knowledge Management*, Blackwell, Oxford, UK, pp. 410–427.
Tulving, E. (2002), “Episodic memory: From mind to brain”, *Annual Review Psychology* Vol. 53, pp. 1–25
Van Merriënboer, J.J.G., Clark, R.E. and de Croock, M.B.M (2002), “Blueprints for complex learning: the 4C/ID model”, *Educational. Technology Research Development,* Vol. 50 No. 2, pp. 39–64.
Winterton, J., Delamare-LeDeist, F. and Stringfellow, E. (2005), *Typology of knowledge, skills and competences: clarification of the concept and prototype.* Centre for European Research on Employment and Human Resources, Final Draft Report.
Wong, B.L.W. (2000), “The Integrated Decision Model in Emergency Dispatch Management and its implications for Design”, *Australian Journal of Information Systems,* Vol. 2 No. 7, pp. 95-107.
Wong, B. L. W. (2004), Data analysis for the Critical Decision Method, in D. Diaper & N. Stanton (eds.), *Task Analysis for Human-Computer Interaction*, Lawrence Erlbaum Associates, Mahwah NJ, pp. 327-346.