TOWARDS THE CLASSIFICATION OF FIREGROUND CUES: A QUALITATIVE ANALYSIS OF EXPERT REPORTS

Abstract

Whilst there is evidence linking informational cue processing ability to effective decision making on the fireground, only a few studies have actually attempted detailed description and categorization of the cues sought by fireground commanders when managing real fires. In this study, thirty experienced firefighters were interviewed across various fire stations in the UK and Nigeria using the critical decision method protocol. Forty one different cues were identified, which were then categorized into five distinct types namely: safety cues, cues that indicate the nature of problem, environmental cues, emotive cues, and incident command and control cues. The paper concludes by evaluating the role of expertise in cue utilization, drawing on evidence from the naturalistic decision making (NDM) literature.

1.0. INTRODUCTION

What does a thick black smoke forcing itself out of the eaves of a roof tell an expert firefighter? What does a cracked wall in a well-alight building signify? What immediately comes to the mind of an incident commander after sighting a large panicking crowd gathered at the scene of an incident? Whilst the possible answers to the above prompts (cues) and their implications for task performance (action) may seem straightforward for experienced commanders, the same may not be the case for novices. Although recognizing a range of task related cues is expected to be a routine task for novices considering they have been trained to do this, prior evidence suggests that novices sometimes struggle to interpret the implications of subtle cues under conditions of extreme uncertainty and time-pressure. Existing studies have shown that simply identifying cues seem insufficient for managing complex incidents (Weick, 1993; Baylor, 2001; Dreyfus, 2004; Klein et al., 2006; Lipshitz et al., 2007), operators must also be able to make sense of what each cue implies, and subsequently use their cue discrimination skills to develop workable action plans. Experts are generally able to recall the cues that aid task performance better than novices, and this has been attributed to the extensive domain knowledge they possess and to the efficient functioning of their schemas (Sweller, 1994; Paas, Renkl and Sweller, 2004; Cowan, 2008; Clark, 2014; Okoli et al., 2014). Schemas contain rules and procedures that can systematically link particular features of a problem to its possible course of action (IF condition, THEN action). In other words, experts often strive to use the general knowledge they have about a domain, or the knowledge they are able to recall from concrete cases, or both, to form action plans and solve new problems (Ten Berge and Van Hezewijk, 1999; Tulving, 2002; Klein, 2003; Feldon, 2007)

What then is a cue? Wong (2000) defined it as any stimulus with implications for action; a feature of the task environment, which through the aid of knowledge and experience has been associated in memory with particular events (Okoli et al., 2016a). Over the years, research on cue-based performance has gained more attention as scholars continue to explore the critical cues upon which experts base their judgment. In both judgment and decision making (JDM) and naturalistic decision making (NDM) literatures, scholars have proposed possible ways through which cue-based learning could be improved for training purposes (Crandall and Getchell-Reiter 1993; Spence and Brucks, 1997; O'Hare et al., 1998; Wong, 2000; Wiggins and O'Hare, 2003; Perry and Wiggins, 2008; Klein, 2008; Okoli et al., 2013; Lamb et al., 2014). Specifically, some of the studies in JDM literature have utilized a cue-based learning approach known as multiple-cue probability learning (MCPL) to explain how decision-makers make sense of information accruing from task related cues (Castellan, 1973; Steinmann, 1976; Juslin et al., 2003; Newell, Lagnado and Shanks, 2007). MCPL at its most basic form is a predictive mode of learning that attempts to predict an outcome on the basis of cue weightings in situations where the relation between the outcome and the cues is probabilistic (Newell et al., 2009). Scholars have examined some of the key conceptual differences between both paradigms, with split opinions regarding their level of competitiveness and/or complementarity (Kahneman and Klein, 2009; Okoli et al., 2014). Essentially, MCPL approach contains mostly studies conducted within laboratory settings where subjects are required to perform 'trivial' tasks, while NDM approach, on the other hand, comprises studies predominantly carried out in naturalistic (field) settings which are characterized by uncertainty, volatility and complexity.

The current study is hinged on the NDM paradigm where scholars are concerned with understanding how experts make difficult task-related decisions using their experience. Within the NDM community, a range of cue-related studies have emerged (See Hoffman et al., 1998; Barton and Sutcliffe, 2009 for review). For instance, Crandall and Getchell-Reiter (1993) studied 22 experienced nurses in a neonatal intensive care unit (Mean years of experience = 13) and found that expert nurses could detect infants with potential life-threatening infections even before carrying out blood tests to verify. The authors eventually identified a range of cues that aided the expert nurses' decision-making, some of which had not appeared in the nursing literature at the time. Also, in their study involving urban firefighters Klein and his colleagues showed that expert firefighters could make quick and accurate decisions under time pressure by matching cues in the task environment against existing prototypes in their memory (Klein, Calderwood and Clinton-Cirocco, 1986).

This insight subsequently led to the development of a decision-making model which the authors termed the recognition primed decision making model (Klein, 2008). The work of Biederman and Shiffrar (1987) further recorded how qualified geneticists could rely on some tacit cues to find out the gender of about 1,000 newly hatched chickens within one hour, with 98% rate of accuracy. In another naturalistic study, Barton and Sutcliffe (2009) were interested in understanding why Wildland operational commanders might have to continue (or discontinue) to follow an action plan (e.g. sticking to direct firefighting or switching to a defensive approach). The authors noted that failure to identify the cues that signal the need for change was often not the problem, but that incidents escalate out of control mainly because officers get so engrossed in an evolving situation that they fail to pause and incorporate these cues into a new understanding of that situation. The authors used the term ‘dysfunctional momentum’ to describe a situation where individuals or teams choose to proceed with a course of *failing* action [italics in original] despite warning cues suggesting an alternative action.

However, despite attempts made by prior research to show how cue identification (or the lack of it) affects task performance, only a limited number of studies have provided detailed categorization of the various cues used by domain experts, particularly in the firefighting domain. To bridge this knowledge gap, the current study employed the critical decision method as knowledge elicitation tool to elicit the various cues which experts utilized in managing complex and high-staked fire incidents. The identified cues were thereafter categorized on the basis of the type of information each cue generated to the officers. The categorization of cues attempted in this paper is conceived as a recipe for knowledge management and organizational learning, particularly in this era where the occurrence of non-routine fire incidents has been on the decline (Lamb et al., 2014). Since novices now have fewer windows of opportunity to gain real-life (operational) experience, the developed critical cue inventory is hoped to play a significant role in the design of training curricula that is more representative of real-life tasks. The overall intention was to find more productive ways through which cue-based knowledge sharing could be enhanced ─ in this case leveraging on what experts know and do on the fireground.

We therefore purport that identifying the exact cues used by experts on the fireground, understanding how they influence fireground decisions and examining how experts discriminate between the various cue classes are a good starting point in the design of an effective cue-based learning protocol. The paper concluded by discussing the role of expertise in the identification and interpretation of task related cues, drawing on insights from the naturalistic decision making (NDM) literature.

For the purpose of clarity, the current study focuses on non-routine fire incidents. Although we acknowledged that firefighters are involved in a number of task related activities such as well (water) rescue, road and rail traffic collision, chemical decontamination and rescue services, the cues generated in this study emerged mainly from fire incidents that considerably challenged officers’ expertise. These incidents include: massive house fires; mechanic workshop and warehouse fires involving combustible substances such as acetylene and LPG cylinders; petrol storage fires; serious fires within task constraining locations e.g. in areas where access to the seat of fire seems problematic; arson cases and road traffic accidents involving fire explosions.

2.0. METHOD

When making critical decisions in most emergency response organizations the cues used by experts mostly lie in the unconscious realm, which they act upon tacitly. Hence eliciting useful information about such cues would often require the application of formal knowledge elicitation tools. As discussed below, we utilized one of such tools in this study ─ the critical decision method.

2.1. Critical decision method (CDM)

With the emergence of expert systems and the growing interest in naturalistic/real world decision making, researchers have in more recent years become interested in eliciting the basis of expert knowledge. This has increased the number of knowledge elicitation tools currently available in the fields of knowledge management and cognitive psychology (see for example, Klein, Calderwood and MacGregor, 1989; Hoffman et al., 1995). The critical decision method was employed in this study, which is “a retrospective interview strategy that applies a set of cognitive probes to actual non-routine incidents that required expert judgment or decision making” (Klein et al., 1989, p.464). CDM was preferred to other methods within the cognitive task analysis family (see Hoffman et al., 1998) because of its proficiency in capturing the cognitive strategies of decision-makers through in-depth cognitive probing (see data collection method below).

2.2. Selection of participants

The sample size for the current study is comprised of 30 experienced firefighters (N=15, UK and N=15, Nigeria), with officers selected from major fire stations across the two study areas. The authors chose UK and Nigeria as study areas ─ initially for the purpose of comparison, but also to identify common themes or similarities that might exist between the two groups in the area of cue-based decision making. However, we wish to clarify that the intention of the current paper is not to discuss cross-cultural differences between both groups of experts, but to report the type of cues identified and utilized by each officer on the fireground. We have elsewhere shown that a significant level of similarity exists between both groups of experts on the basis of the type of cues sought and utilized on the fireground (Okoli et al, 2016a; Okoli et al., 2016b). For example, environmental cues such as wind velocity, wind direction and external temperature, and fire-related cues such as smoke colour, size of fire and flame texture were not only found to convey similar meaning to officers but also affected response effort alike, regardless of location. Building on these insights we first aggregated all the cues common to both groups of experts and then categorized them.

Certain criteria were considered in the study in order to ensure the right set of participants were recruited. Firstly, participants were carefully selected on the basis of their rank/position. This was to ensure that the selected officers are verifiably real experts. Secondly, all participants must have been personally involved in managing real-life fire incidents for which they made independent decisions with little or no supervision from their superiors. This implies that potential participants must have at least operated as operational commanders i.e. officers who take responsibility and leadership of managing one or more fire engines at the scene of an incident.

Participants were also recruited through peer nomination – this process of 'peer nomination' is also known as 'Snowballing' where the researcher asks a key informant if they can recommend another potential participant whom the researcher might wish to contact for interview. The chain went on and on until the required sample size was reached. This was the case both in the UK and Nigeria, and participants were willing to suggest other officers whom they felt met the study criteria.

2.3. Data collection and Analysis

The study employed the full CDM procedure (see Klein et al., 1989; Hoffman et al., 1995; Hoffman et al., 1998). Participants were first asked to recall and narrate a memorable fire incident, regardless of when the incident occurred — with emphasis on incidents that particularly challenged their expertise. It was important to limit the choice of incidents to non-routine incidents as managing such incidents has been shown to invoke greater use of tacit knowledge compared to routine incidents (Wipawayangkool and Teng, 2014). This explains why managing routine incidents is more likely to call for the skills of experienced officers.

Participants narrated the incident they have chosen from start to finish, with minimal interference from the investigator. This was to ensure that a rich context of the incident was obtained, including a detailed account of the sequence of proceedings that occurred (for a detailed discussion on CDM procedure see Hoffman et al., 1998; O'Hare et al., 1998). After narrating the incident, a timeline was sketched by the interviewer and participants were asked to indicate points along the timeline where key actions took place i.e. points where important decisions were made (see Table 2 for sample of decision points). A decision point, which is the unit of analysis in the study, was defined as any point in the timeline of an incident where participants admitted following a particular course of action even though other options were potentially available. The incident timeline and decision point identification stages were followed by probing each decision point, using a set of cognitive probes to enhance the knowledge elicitation process (See Table 1). Although the cognitive probes shown in Table 1 covered a range of themes such as the cues sought by experts, the goals pursued at each decision point, the information utilized at each decision point, it is important to emphasize that the subject of cues appeared central across the entire probe questions. Nearly all decision points (sets of actions taken by the officers) were informed by certain cues, either from sources internal or external to the decision maker. Essentially, data used in the cues categorization process was not limited to a single probe question, rather insights were generated from the analysis conducted across the thirty incident reports. Data analysis focused specifically on the cues sought by experts, the cue sources and the type of information each of the experts generated from each decision point (see Table 3 for sample of coding process).

For the purpose of quality appraisal, two reviewers who are co-authors of the current paper were involved in the coding and categorization process. Random samples of interview excerpts were provided to the reviewers for evaluation, after which the three authors converged to agree on the final coding frames.

Table 1: Sample of CDM probe questions used in this study (Adapted from Hoffman et al., 1998)

Probe Type	Probe Content
Cues	What were you seeing, hearing or smelling that helped in formulating your action plans?
Knowledge	What information did you use in making these decisions and how was it obtained?
Analogues/Prototypes	Were you reminded of any previous incident(s) while managing this particular incident
Level of Novelty	Does this case fit a standard or typical scenario? Does it fit a scenario you were trained to deal with?
Goals	What were your specific goals and objectives at each decision point?
Options	What other courses of action were considered or were available? Why were these options not considered?
Rule based/Adaptive/ Creative decisions	What rules were you following at each decision point? At what point did you go beyond following SOPs or firefighting rules? Were you being creative with any of your decisions?
Most important information	What was the single most important information that you used in formulating your action plans?
Experience and prerequisite knowledge	What specific training or experience was necessary or helpful in making these decisions? What training, knowledge, or information might have helped?
Time pressure	How much time pressure was involved in making each of these decisions? How long did it actually take you to make these decisions?
Errors	What mistakes are likely at each decision point? Did you acknowledge if your situation assessment or option selection were incorrect? How might a novice have behaved differently?
Hypotheticals	Briefly explain what you would do if you arrived at the scene of a serious fire and discovered that you have very little information about what was happening and yet have to make decisions whether to employ an offensive or a defensive attack?

Each interview lasted between 1hr-2.30hr. Notes were taken as the interview progressed and a diagrammatic representation of the timeline was sketched during the interview to enhance memory recall of the incidents. A total of 134 decision points were obtained from the thirty interviews (see sample of decision points in Table 2) and CDM probes were applied to each decision point so as to gain a deeper understanding of the proceedings of events. For the purpose of this paper, the aim of analysis at each decision point was to better understand exactly what an expert firefighter was "seeing" "hearing" or "perceiving" that necessitated making certain decisions over other potentially available alternatives (See sample of excerpts and coding process in Table 3). Capturing and categorizing these cues (as detailed in Table 4) were seen as a useful way through which knowledge about cues can be transferred from experts to novices.

Table 2: sample of selected decision points from both UK and Nigerian firefighters

Decision points	Type of incident	Location
Requested specialist appliance (transition from water to foam attack)	Petrol fire	UK
Called for more appliance from control room (asked for reinforcement from 2 to 7 fire engines)	Garage Workshop fire	UK
Started delegating tasks to other personnel while still enroute the incident scene	Office fire	Nigeria
Considered evacuation of the fire crews i.e. switched to a more defensive firefighting strategy	School fire	UK
Demolished the entrance door in order to gain access to the seat of fire	House fire	Nigeria
Spotted areas where walls have been weak and avoided direct firefighting around there	House fire	Nigeria
Started firefighting operation from unaffected areas in the building.	School fire	Nigeria
Made use of hosereel in extinguishing the fire instead of mainjet.	House fire	UK
Broke the glass leading to the building so as to gain access to the seat of fire.	House fire	Nigeria
Withdrew the crews because the fire grew out of control	School fire	UK
Immediately took charge of the incident without waiting for any formal handover	Garage Workshop fire	UK

3.0. RESULTS

Following each interview excerpt below are participants' name, years of experience, rank, and incident location. To maintain anonymity and confidentiality of participants, it was important to change their real names to pseudonyms (false names), while other details remain unaltered.

3.1. Critical cue inventory

We define the critical cue inventory (CCI) as a range of cues that have been collected and compiled from coded incident accounts for the purpose of developing instructional guidelines mainly for cue-based learning. A detailed qualitative classification of the elicited firefighting cues is discussed in turn below:

Table 3: Sample of excerpts showing how cues were coded and abstracted into categories

Interview excerpts	Codes	Sub-categories
…because I could see the way that the smoke was behaving and the lack of flame and the colour of the smoke that confirmed to me that it was safe for firefighters to use the ladder to go in through the doors (Jade, 15, Crew Commander, UK)	• Smoke • Lack of flame • Colour of smoke • Use of ladder	• Visible cue (CINP) • Visible cue • Visible cue • Action
Also because the sympathizers have been trying before our arrival, so far they have not been able to conquer the fire, it means that the fire is not easy (Sammy, 8, Crew commander, Nigeria)	• Attempts by crowds • Difficult fire	• Emotive cue (EC) • Implication of cue
The first thing was the size of the fire and its intensity. The next was the potential for it to spread, the potential for widespread damage as a result of our actions. The obvious ones was what I could see; there was access to the seat of the fire which we didn't see before (Patrick, 32, Asst. Fire Chief)	• Size of fire • Intensity of blaze • Potential of spread • Access to seat of fire	• Visible cue • Visible cue • Potential hazard (SC) • Insight
The smoke/flame is also an important source of information. When the smoke is white/light then the fire is not dangerous. But when you see the smoke deep and dark, it means the fire is too dangerous" (Kevin, 8, Watch commander, Nigeria)	• Nature of smoke colour and flame • Smoke colour • Discrimination of smoke colour	• Visible cue • Visible cue • Cue discrimination skill
So we arrived find not only a fully developed fire that is burning quite well, but people from the balconies, on the windows all shouting and screaming for help (Lambert, 26, Watch commander, UK)	• Fire intensity • People screaming help	• Visible cue • Emotive cue
I had to look at the stability of the building because the window had come out which is a supporting structure in itself and that the floor actually dropped (Dake, 17, Watch commander, UK)	• Stability of building • Collapse of window • Dropping of floor	• Potential hazard (SC) • Potential hazard • Potential hazard
We found that the petrol was already licking, moving towards residential areas….. The erosion has actually taken the fuel to a distance of about 2km, and we had to follow it like that, spraying chemicals along the line (Mike, 28, Asst. Chief fire supt, Nigeria)	• Licking petrol • Direction of hazard • Use of chemicals	• Potential hazard • Potential hazard • Action
So my first decision was about when am I taking over. I know I have got a significant incident on my hands, I have to take over, I'm obliged to when it gets to 5 pumps" (Darren, 17, District commander, UK)	• Awareness of take-over duty • Awareness of take-over time	• Situation Awareness • Command and control (ICCC)
The wind was like swirling, and the fire was actually drawing the wind in. So even on the opposite side of the fire you might have had a wind say 5, 6, 7 10 miles/hr, it's probably 40-50miles/hr on the opposite side, in the area that I was in because it was being swirled around and the fire was actually drawing all the oxygen in to feed the fire. The trees were sort of blowing, it's like a full-scale. I have never experienced anything like it. (Dunham, 13.5, Station manager, UK)	• Wind movement • Increase in fire intensity	• Environmental cue (EVC) • Implication of cue

Note: CINP (cues that indicate the nature of problem); EC (Emotive cues); SC (Safety cues); EVC (Environmental cues) and ICCC (Incident command and control cues)

3.2. Classification of cues

As shown in Table 4, thematic analysis of the interview reports revealed 41 different cues experts sought under various task constraints. These cues were further categorized into five distinct types:

(i) ***Safety cues:*** As much as firefighters have an obligation to save lives and properties, they are required to do so within a reasonable boundary of safety. This implies that incident commanders would most times have to rely on safety related cues in order to determine the most appropriate options. Cues that belong to this category primarily influence officers' risk taking behaviour and suggest if, for example, it is more appropriate to adopt a precautionary approach or whether it is best to initiate direct firefighting. Safety related cues therefore ensures that optimum balance is reached between taking reckless risks on one hand and being unnecessarily risk averse on the other hand. Examples of safety related cues include cracked walls in a well-alight building, signs of roof collapse, presence of combustible substances such as acetylene or LPG cylinders (see list on Table 4).

Table 4: Critical cue inventory from elicited expert knowledge

Safety cues	Cues that indicate the "Nature of Problem"	Environmental Cues	Emotive cues	Cues that inform incident command and control decisions
• Cracked wall • Falling wall • Roof condition (possibility of collapse) • Substances present/perceived to be present in a building e.g. combustible materials such as petrol, acetylene cylinders, LPG cylinders • Potential of fire spreading • Smoke behaviour (flashovers, backdrafts) • Location of the seat of fire • Location of unaffected properties • Type of building (terraced, block of flats, single-story, multi-storied) • Entry point (accessible, obstructive) • Category of victims trapped (elderly, disabled, mentally challenged)	• Size of Fire • Intensity of fire • Pattern of flame movement • Egress of the flames • Smoke colour (yellowish rainbow, blue, thick black) • Smell/odour of smoke and burning substances • Texture of smoke (thick, light, cloudy) • Severity of physical damage • The nature and extent of injury suffered by victims • Room temperature (A room on fire can sometimes be as hot as 1000^{o}C) • Type of materials burning or class of fire (metal fire, gas fire, batteries, acetylene) • Noise of vibration on the ground • The intensity of heat emitted from the blazing fire to the environment • The quantity of water that has been used up in the process (10,000 litres show how serious a fire is)	• Wind direction (is the wind blowing towards or away from the fire?) • Wind speed/intensity • External temperature/climatic condition (Hot, warm, harmattan, cold) • Catchment area (Residential, Factory, Industrial, Rural, City) • Location of incident (Rural or Urban area) • Distance to water supply (availability and proximity of hydrants) • Topography of the street e.g. steep slope, high slope	• Verbal threat from victims • Shouts for "help" from crowd • Level of panic displayed by the crowd • Cry and wailings from trapped victims • The number of passers-by at the scene of incident	• The rank/level of experience of the officer currently in charge • The number of pumps deployed (a more superior officer takes over when the number of on-scene pumps gets to five • The size of the building (building size determines whether sectorization is needed • Height of the building (e.g. if building is too high beyond the reach of a ladder, then the use of an aerial appliance becomes necessary)

The excerpts below show some useful information regarding experts view on safety related cues:

“If we open the door and the smoke was coming out and then suddenly starts to suck in- then we know the fire is waiting to get oxygen so we pull the door shut. You see what I mean- it’s a visual signs of what is happening in that building. And you get like pulsing- sometimes it sucks in and blow out, suck in and blow out- again that’s another dangerous sign” (Dickson, 23, Crew commander, UK)

“We had to fight the fire from the rear [so as to block damages] because it was spreading towards the rear from the front …..also because the wall may fall upon any of the officers if we fight from the front” (Knight, 8, Watch commander, Nigeria)

The officer in the first excerpt emphasized the importance of understanding the movement and behaviour of fire in a building. There could be misleading signals suggesting safe access into an engulfed building even when it is unsafe to do so. Hence, fire crews may end up endangering their lives by their failure to make sense of how these subtle safety cues evolve, exacerbated also by their inability to deploy standard entry control procedures. As an illustration, the officer provided examples of the possible occurrence of a “flashover” (the sudden and simultaneous ignition of substances in a room due to excessive high temperature) or a “backdraft” (smoke explosion that occurs when additional oxygen is introduced into a smouldering fire) in a building that is perhaps perceived to be safe. In essence, the absence of smoke or flame in a building does not necessarily guarantee safety or free access into the building. In the second excerpt, the officer explained the basis of his decision to fight the fire from the rear end of the building after assessing the direction of movement of the fire as well as spotting cracked walls.

Hence, in contrast to other cue categories, safety cues present decision makers with important questions such as: how is this situation likely to affect members of the public? What hazards are present and how are they likely to affect the fire crews? Are the fire crews safe enough?

(ii) ***Cues that indicate the “nature of problem”:*** this category of cues comprises both visible and perceptual signals that help define the ‘criticality’ of an incident. Cues that belong to this category e.g. smoke colour, smoke texture and flame movement are often important as they provide useful information to officers and generally play a major role in determining what the most appropriate action plans would possibly be. With the aid of these cues officers are able to decide whether or not to request additional response resources and what those should be, as well as make sense of the type of substances burning (i.e. predict the class of fire involved). By virtue of their cue discrimination skills, experienced officers tend to understand the difference between the colour/texture of smoke oozing out from combustible substances (class B fire) and the ones generated from carbonaceous substances (class A fire).

The first excerpt below shows how one of the commanders used the size of fire and the intensity of its blaze to judge how severe an incident was, while the second illustrates how an expert used the extent of burn suffered by a victim to judge the victim's chance of survival.

> *"Definitely you will see where the fire is coming from…. the wall will let you know which one the fire started with, you will see it. The room that the fire started with will be rigorously heated. Secondly is that you will see that the damage will be too much there" (Young, 8, Fire Supt. Officer, Nigeria)*

> *"The most important piece of information I need to know is what caused the burns, and the severity of the burns as well; and the only way you could do that is to go looking at him. You make your own mind up; anything above 30%, you are dead - six finger prints (Brown, 27, Crew commander, UK)*

By assessing the proceedings of events in a task environment, this category of cues helps officers gain better *awareness* of a seemingly complex situation. Thus, in contrast to safety cues which mostly aim to recommend what the most appropriate risk taking behaviour should be for officers, cues that indicate the nature of problem helps predict the severity of an incident, allowing the officers to become *situationally aware* of happenings in their environment. While the terms "situation assessment" and "situation awareness" are sometimes used interchangeably in the literature (Gore et al., 2006; Lipshitz et al., 2007; Klein, 2008), they are treated as separate but inter-related concepts in this paper. The former deals with the aspects of "sizing up", while the latter is mainly concerned with interpreting or "making sense" of the identified cues.

(iii) ***Environmental cues:*** this category of cues is mainly generated from external and environmental sources and include, for example, atmospheric temperature, wind speed, wind direction, humidity and topography. The most notable difference between environmental cues and other cue categories is that the former usually exceeds what incident commanders can easily influence or control. Operators are therefore required to possess extensive knowledge of the firefighting domain to be able to make sense of these cues and to understand their implications for task performance. In this study, experts emphasized the difficulty fire crews often encounter when carrying out firefighting tasks under unfavourable climatic conditions such as intense heat or extremely windy conditions (see excerpts below). Carrying out response activities in these conditions was also found to increase physical and mental fatigue amongst firefighters.

The excerpts below show the possible ways through which environmental factors affect firefighting tasks from the point of view of the participants:

> *"Because it was Harmattan season; you know there is Harmattan wind that use to blow early in the morning, so we had to back the wind, we cannot confront the wind as it was blowing towards us and affecting our firefighting operations" (Jack, 30, Chief fire superintendent, Nigeria)*

> *"The location of the incident made it difficult to get water because the hydrant was far. I decided to use hose reel because it uses less water" (Isaac, 13.5, Crew commander, UK)*

It is worth mentioning that the term "environmental" does not only represent climatic conditions such as wind, temperature, humidity, but also includes external factors such as topography, water network, nature of incident scene e.g. availability of rivers/canals, location of hydrants etc. (see Table 4)

(iv) ***Emotive cues:*** this category of cue mainly emanates from emotional and/or psychological behaviour displayed by or inferred from both victims and passersby. This is particularly so in incidents where the relevant cues required to develop response plans are not directly visible from the incident itself, or when there is need to draw additional information from people's "body language". Considering that these cues require making sense of people's response to stimuli, incident commanders are expected to possess sound emotional intelligence in addition to having extensive technical knowledge of their work domain. In the current study, emotive cues (emotional outbursts, show of panic or restlessness) played an important role in influencing experts' judgment and provided officers with actionable information even before arriving the scene of incident. The incident reports showed that experts sometimes leverage on their experience to draw important clues from the "voice tone" of a caller, from which an assessment of the severity of the incident is then made. In other instances, experts are also able to build a mental picture of the severity of an incident e.g. by observing the psychological behaviour of the crowd:

> *"I knew we had a job as soon as we arrived the venue. The reason being that there was a crowd outside the building. If there were no one outside that building it could be doubtful, but when you see people as you are pulling up saying help! help!, that gives you a great indication that something is going on" (Brown, 27, Crew Commander, UK)*

Despite the relevance of emotive cues in this regards, some of the participants warned against being unnecessarily reactive to mere emotional outbursts. The interview excerpt below supports existing claims (e.g. Slovic, 1993; Kahneman and Klein, 2009) that laymen (i.e. untrained firefighters) are often more emotional than domain experts and therefore more prone to subjective judgment:

> *"Sometimes the crowd make it look more serious than it is through the way they scream, shout or react to smoke or small fires" (Mike, 28, Assistant Chief Fire Supt, Nigeria)*

The ability to differentiate between emotive cues and mere false signals, however subtly, is therefore key to fireground decision making. As shown in our previous study (Okoli et al., 2016a), expertise lies in knowing which emotive cue is worth paying attention to and which is not.

v) ***Incident command and control cues:*** this category of cues, which was predominantly reported by the UK experts, often informs the need for a takeover decision. These cues help identify if/when it is best for a superior officer to take over command responsibility from a lesser ranked operator. There are two dimensions to the way these cues are applied as far as fireground decision making is concerned: firstly, knowing when a superior officer ought to take over from a lesser ranked officer and secondly, knowing when to allow a lesser ranked officer carry on with overall incident command responsibility. Whilst it is typical in the UK for the most experienced officers (in terms of length of service) to take over leadership position upon arriving at fire scenes, there are few instances where lesser ranked officers are handed overall command and control responsibility. In more recent times, the rule of thumb is to allow the officer that has gained the best situation awareness of an incident to take charge, regardless of rank. The interview excerpts below showed instances where a superior officer had to take over command and control responsibility as a matter of urgency:

> *"I walked down looked for the officer in charge, the incident commander, at the same time I saw these guys trying to mobilize a firefighting jet in between this house and the next door neighbor's house on an alleyway to try and take it round the back to fight the fire from the back because that's where the main seat of the fire was. Now I haven't taken over, I haven't even seen the incident commander at that point but I intervened at that point because I know No we won't do that" (Troy, 27, Area commander, UK)*

> *"So my first decision was about when I'm I taking over. I know I have got a significant incident on my hands, I have to take over, I'm obliged to when it gets to 5 pumps" (Darren, 17, District commander, UK)*

In the first excerpt, a superior officer, an area commander, had to takeover command and control responsibility from a watch commander after spotting some potentially wrong tactics being deployed by the firefighters. The officer reported he had to step in immediately to rectify the action plans without having to go through any formal hand-over procedure. In the second excerpt, as with the first, another superior officer, a district commander reportedly took over from a watch commander after perceiving that the fire was getting out of control. Understanding the cues that engendered these takeover decisions is therefore perceived as crucial for the purpose of training potential incident commanders.

4.0. DISCUSSION

The study set out to identify and categorize various cues utilized by experienced fireground commanders in the UK and Nigeria, with respect to a retrospective incident reported by each expert. While we acknowledge that the list of cues presented in Table 4 is not exhaustive, we also note that the total number of elicited cues seem quite encouraging in relation to other cue elicitation studies (Calderwood, Crandall and Baynes, 1990; Wong, 2004; Wiggins and O'Hare, 2003; Perry and Wiggins, 2008), outnumbering even those identified by Klein and his colleague in their seminal work with urban firefighters (Klein et al., 1986).

The interview reports reveal that identifying cues is not necessarily a challenging task on its own, particularly when relevant training has been acquired. The more challenging cognitive task actually lies in understanding the implications of the identified cues and being able to prioritize actions amidst rapidly evolving conditions. We argue that the ability to make sense of any cue firstly requires building a strong knowledge base about the firefighting domain. This includes understanding the dynamics of fire, smoke movement patterns, chemistry of combustion and fire behaviour ─ all of which appear to be built and refined through experience. Previous NDM studies across domains such as sports, medicine and midwifery, education, aviation, military, ambulance and firefighting have shown a positive relationship between actors' years of experience and their ability to recognize and interpret cues (Wong, 2000; Baylor, 2001; Falzer, 2004; McLennan et al., 2006; Fessey, 2002; Dreyfus, 2004; Tissington and Flin, 2005; Kermarrec and Bossard, 2014).

Thematic analyses of the interview excerpts suggest the existence of a positive link between identified cues, prior experiential knowledge about a task domain and subsequent response plans. The cues identified on the fireground must first generate useful information to experienced officers, which they must then process, interpret and translate into useful actions (see excerpts shown on Table 3). In the cues that indicate the nature of a problem, for example, an association was found between identified cues (e.g. the size of a fire) and subsequent response plans (e.g. deploying specialist appliance). In safety cues, reports show that spotting a cracked wall in a well alight building mostly suggests the need to prioritize fire crew safety, with the possibility of initiating defensive as opposed to offensive tactics. In environmental cues, experts revealed that carrying out a response effort in extremely windy and non-windy conditions could both be counter-productive. The former condition was reported to increase both the chance of injury to firefighters and the likelihood of fire spreading to surrounding properties, while the latter would most likely dense-up smoke, thereby creating communication difficulties amongst crew members.

The accuracy of the interpretations an officer provides regarding a cue is contingent upon the strength of the patterns that have been chunked in their memory. Even when an incident presents visible cues, the onus still lies on the officer to make sense of such cues using their experience. The above assertion gives credence to prior research suggesting that the length of active service and the quality of experience gained are both crucial to building a repertoire of *patterns*, or what Chase and Simon (1973) and Gobet (2005) called *chunks* and *templates* respectively. In their early study with chess players, Chase and Simon (1973) hypothesized that experts can rapidly recognize key features of a problem using their perceptual and cue discriminating skills. The authors further tested this hypothesis through an experiment that involved expert and novice chess players, which subsequently led to the development of the 'chunking' theory (Chase and Simon, 1973). The chunking theory is based on the notion that experts are often able to store a large amount of information in their long term memory, usually as a single entity, which they rely upon to direct their future course of action (Gobet, 2005). In two different tasks presented to the two groups of chess players (chess masters and novices), the authors found that the former were able to memorize and reconstruct a chess position better than the weaker novice players. Simon and Chase (1973) linked such exceptional performances to the larger amount of chunks the chess masters had acquired compared to their novice counterparts.

The current study also showed that the way experts generally sought and utilized emotive cues seemed to contradict the claims made by some cognitive theorists (Easterbrook, 1959; Epstein, 1994; Shapiro and Spence, 1997; Sinclair and Ashkanasy, 2005). The cue-utilization theory (Easterbrook, 1959), for example, suggests that consistently arousing the emotions of task performing individuals through an external stimulus would likely reduce the number of cues they are able to identify, and in turn affect task performance negatively. The theory further suggests that the more people are exposed to the cues that arouse their emotion the more likely they are to be distracted away from the main tasks to be performed. Unfortunately, there was little or no evidence from this study to support Easterbrook's theory as none of the interview transcripts seemed to support the claim that experts were distracted from identifying cues. This also holds true for the twelve "emotional" incidents that involved loss of lives and massive loss of properties (UK= 5, Nigeria=7). We instead support the notion that experienced commanders are able to cope with multiple information sources by filtering out what they perceive to be irrelevant information or noise (see Okoli et al., 2016 for details). By so doing, the short term memory is preserved from information overload, thereby ensuring that officers are not distracted away from the main firefighting tasks.

Previous studies have shown that competence in task performance is not always a function of the decision maker's cognitive capability, but more on the "structure" of the task environment (Calderwood, Crandall and Baynes, 1990; Goldstein and Gigerenzer, 2002; Salas, Rosen and DiazGranados, 2010). The word structure in this context represents the extent to which informational cues are present in the environment as well as the ease of identifying them. Kahneman and Klein (2009) used the term zero-validity to describe environments where identifying cues often proves difficult, or where the cues identified mostly fail to correlate with subsequent response action. It can therefore be argued that one of the most important concerns for fireground decision makers is whether or not a task environment provided adequate informational cues upon which decisions are to be based. The above interview excerpts (see also Table 3) suggest that fireground commanders often rely on cues to develop workable action plans, although it would have been more interesting to investigate the effect that lack of experts' reliance on cues would have also had on task performance.

The classes of cues presented in this paper are aimed at improving existing training protocols for potential incident commanders. A wide range of training scenarios (learning tasks) could be designed using one or more cue lists provided in Table 4, where facilitators could aim to improve learners' understanding on how various cue categories might likely affect task performance under varying task constraints. Developed learning tasks could also be used to identify additional training needs that learners might benefit from e.g. providing additional emotional intelligence training to the less experienced officers so as to develop their problem solving and perceptual skills. Such training could subsequently facilitate learners' cognitive schemata until they are able to differentiate between emotive cues worth attending to and those that are mere false alarm. Specifically this study supports existing research suggesting that expertise in the firefighting domain is more about leveraging upon one's experience to differentiate between cues that are needed for task performance and those that are mere distractions.

5.0. CONCLUSION

This study set out to outline the cues sought by experienced firefighters using the critical decision method (CDM) as knowledge elicitation tool. The importance of cue elicitation cannot be overemphasized in a complex domain such as firefighting as it plays a crucial role in the design of training curricula. It therefore holds true that if the cues experts utilized in formulating their action plans are known, a decision support system that has the potential to aid decision-making amidst various task constraints could subsequently be developed.

The insights generated in this study have some implications for training. For instance, we recommend that individuals with less experience are first encouraged to enrich their mental models, build sufficient patterns and gain more real life experiences before any meaningful assessment of their cue discriminating skills is attempted. Since the elicited cues from this study were direct outputs of real-life incidents as opposed to contrived tasks, it is hoped that the efficiency of cue-based knowledge transfer from experts to novices would be enhanced through the development of appropriate learning tasks that are tailored towards the naturalistic environment. Future research is ongoing and focused on developing 'learning tasks' from the elicited cues for novice firefighters as part of their training curricula.

6.0. REFERENCES

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