Training for improvisation in emergency management: opportunities and limits for information technology

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Abstract: Skill in improvising enables emergency management personnel to make creative decisions under time constraint, even when risks are high. It therefore complements skill in plan-following, which is particularly appropriate when the current emergency is similar to a past one. This paper develops recommendations on how to use Information Technology (IT) in the design of training programmes for improvisation in emergency management. It identifies and describes key training outcomes and techniques, and provides an assessment of how training platforms can be used to support achieving the training outcomes. It therefore provides an agenda for new training methods and guidelines on how IT may best be used in executing this agenda.

Keywords: emergency management; training; improvisation; Information Technology; IT.

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1 Introduction

The ability to act creatively and successfully under pressure is a hallmark of the skilled emergency manager. Indeed, as demonstrated by the responses to many emergencies (most recently, the 2001 World Trade Center attack (Kendra and Wachtendorf, 2003; Mendonça, forthcoming) and the US hurricanes of 2004–2005 season) an ability to improvise remains crucial to the success of planning and response operations (Mileti, 1999). Yet the means by which this ability is developed and enhanced are under-explored, often ascribed to years of experience or to the manager's particular personality.

This paper develops a set of recommendations on how information technologies can be utilised to support training for improvising in emergency management. To inform these recommendations, a series of questions is proposed, which are linked through 'concept matrices' (Salipante *et al*., 1982; Webster and Watson, 2002). These matrices (shown as tables) enable the salient concepts to be carried forward to the paper's conclusion.

The paper proceeds as follows. Cognitive processes involved in improvising are reviewed in order to identify a set of training needs and outcomes for improvisation in emergency management (Section 2). By drawing upon how training for improvisation is accomplished in jazz, training methods for improvisation in emergency management are proposed. Requirements for environments in which these techniques may be trained are then developed (Section 3). We then consider how information technologies may best be used within training platforms to support the implementation of these environments (Section 4). The paper concludes with a discussion of the implications of this work for the design of training programmes (Section 5).

2 Training needs for improvisation in emergency management

Training may be defined as a method for developing knowledge, skills and attitudes (Salas and Cannon-Bowers, 2001). An important first step in developing a training programme is to identify training needs (Goldstein, 1993), achieved here by discussing the decision setting and tasks in emergency management.

2.1 The decision setting and task

Tasks associated with managing an emergency usually include monitoring operations during normal conditions, selecting an appropriate procedure when planned-for contingencies arise, and revisiting the appropriateness of these procedures as other potentially disruptive events occur (Beroggi and Wallace, 1994). Unplanned-for contingencies – events for which no planned-for procedure exists – create the need for the responding organisation to develop and deploy new procedures in real-time. In contrast, emergency preparedness entails organising for response activities before disaster occurs (Kreps, 1991), and thus includes planning and training activities. When emergencies are of sufficient scale, they are likely to require coordination and communication among numerous individuals and organisations, often in order to reason about the behaviour of complex, dynamic systems. To inform training for improvisation, it is advisable to review theory of when and how groups of decision-makers depart successfully from planned-for activities.

2.2 Improvised decision-making

Improvisation may be defined as a combined behavioural and cognitive activity that requires serial creativity under tight time constraint in order to meet performance objectives (Mendonça and Wallace, forthcoming-a). Understanding of cognition in highly non-routine situations (*e.g.*, those in which unplanned-for contingencies arise) can lead to improvements in training for decision-making in these situations (Klein, 1993). Indeed, training has proven capable of improving human ability to recognise salient similarities and differences between current and past situations – even at a very fine-grained level (Klein, 1993). This section briefly reviews key cognitive processes involved in improvising in emergency management.

Following the occurrence of an unplanned-for contingency, a two-stage process may occur (Mendonça, forthcoming). In the first stage, the responding organisation recognises either that no plan applies to the current situation or that an applicable plan cannot be executed. In the second stage, given that the need to depart from planned-for procedures has been recognised, the responding organisation must develop and deploy one or more new procedures. The improvisation may range from substitution (*e.g.*, using a close substitute resource for one that is unavailable) to the construction of new procedures (*e.g.*, developing an entirely new procedure). In the case of substitution, the responding organisation 'mixes and matches' existing procedures and/or the materiel used in them. At the other end of the spectrum, the organisation must develop new procedures and possibly find new materiel for use in those procedures. More radically, it may also entail changing the goals of the response (*e.g.*, deciding in the field that the real problem to be solved is providing shelter in place rather than evacuating).

2.3 Summary of training needs

The question of *when* to improvise may be conceptualised as a categorisation or choice problem, in which the ability or likelihood of a decision-maker to categorise correctly is influenced by a number of factors, such as penalties associated with making an incorrect choice and the likelihood that the response will succeed (Mendonça, forthcoming). Increased time pressure and risk may also influence how the choice is made (Smart and

Vertinsky, 1977), in part by reducing the inclination to improvise given that the need exists to do so (Weick, 1993). The correct choices in this problem (improvising when no planned-for procedure applies or can be executed; not improvising when a planned-for procedure does apply and can be executed) have been fairly well investigated (*e.g.*, Hayes-Roth and Hayes-Roth, 1979; Cohen, 1989; Mendonça and Wallace, forthcoming-a). There are also numerous studies of one incorrect choice (failing to improvise when an appropriate planned-for procedure either cannot be found or cannot be executed) (*e.g.*, Weick, 1993). The second incorrect choice (improvising when a planned-for procedure applies and is executable) is certainly under-investigated.

The question of *how* to improvise may be conceptualised as a search and assembly problem, which may be influenced by factors such as time available for planning, risk in the environment and the results of prior decisions (Mendonça, forthcoming). Knowledge of planned-for routines, and the situations for which they are appropriate, can contribute to this ability, provided that response personnel can recognise when it is appropriate to depart from plans. Exposure to a wide variety of situations may also contribute to the capability to improvise.

Four overall training needs that pertain to improving skill in improvising may thus be identified: recognising *when* it is appropriate to depart from planned-for procedures; learning *how* to develop and deploy new procedures in a serial fashion under time constraint; *communicating* across multiple decision-makers; making *inferences* about the present and likely future states of complex systems such as physical/public infrastructure (Rinaldi *et al*., 2001; Mendonça and Wallace, forthcoming-b). Table 1 summarises the training outcomes associated with these cognitive activities in the context of improvisation.

Table 1 Training needs, activities and outcomes

Needs	*Activities*	*Outcomes*
1. When	Categorisation	Recognise the occurrence of unplanned-for contingencies
2. How	Search	Retrieve or infer procedures that are nearly appropriate for the situation
	Assembly	Generate one or more new procedures that are derived from existing procedures
	Constraint satisfaction	Ensure that new procedures can be executed in a timely fashion
3. Communication	Communication	Communicate and collaborate with decision-makers
4. Inference	Inference	Reason about physical systems and the models that represent them

3 Training for improvisation

Improvisation and plan-following differ in salient ways (Weick, 1998). Yet while the practice of improvisation in emergency response is becoming increasingly better-studied, methods for training for improvisation are understudied. It is therefore useful to consider briefly how improvisation is learned outside the domain of emergency management (Mendonça and Wallace, forthcoming-a).

We first survey the techniques used to achieve the training outcomes given in Table 1 in the domain of jazz music, then show how these techniques may be adapted to the domain of emergency management. Next, we develop a set of environmental variables that must be manipulated in order to assess the efficacy of these techniques.

3.1 Training for improvisation in jazz

Jazz musicians plan to improvise. While the methods that constitute this planning are varied, many are well-known and reliable. A reasonable place to begin in structuring training for improvisation in emergency management is therefore with a translation of some of the more proven methods from jazz. Sources include Berliner's (1994) and Sudnow's (1995) detailed descriptions of the progression of individuals from non-improvisers to improvisers, as well as Bailey's (1992) series of interviews with world-class improvisers in various forms of music.

Improvisation in jazz is a continuous and serial process, involving conceiving, interpreting, articulating and remembering an unwritten, evolving score (Berliner, 1994). Improvisers must negotiate their performance over time, continually contextualising the current action in terms of present and likely future actions (Sarath, 1996). Training techniques in jazz balance a high degree of memorisation (*e.g.*, of sets of notes that sound musical when played in relation to a certain chord) with practice in creative performance. Memorisation entails encoding theory (in the form of rules) into long-term memory. The fast tempo of much jazz forces jazz musicians to draw from this memory (Johnson-Laird, 2002) – even when doing so reduces the creativity of their performances. It is therefore necessary for them to be on guard against using well-practised patterns.

To guide their cognition in performance, improvisers may employ a *referent* (Pressing, 1988; Sarath, 1996; Pressing, 1998), which may be defined as an underlying format, such as 'the harmonic-rhythmic framework of the composition' played by the improviser (Pressing, 1988). The purpose of the referent is to enable the player to generate improvisations which are appropriate for the current performance but are also novel. Referent-based improvisations may range from the "recognizable ornamentation of an existing theme" to the real-time development of new themes (Kernfeld, 1995). During practice, improvisers may practise *repeating recorded solos*, especially on different recordings of the same tune, in order to determine the referent that guides a solo.

In learning to recognise when to improvise, performers come to realise that the occurrence of unplanned-for contingencies (whether errors or opportunities) "must be accepted as part of the irrevocable chain of acoustical events, and contextually justified after the fact by reinforcement or development" (Pressing, 1984). Because jazz, like emergency management, is 'of the moment', musicians must be well-practised in recovering from errors (this is commonly called a *making a save*) (Berliner, 1994). To practise skill at making saves, improvisers may introduce errors or random choices into their performances, creating problems which they must work themselves out of.

An instructor may sometimes cut short a player in mid-solo, then ask for a repetition of what has just been played. This *stop and repeat* technique improves the capability of improvisers to attend to the details of the current performance. A similar technique is for the instructor to begin a solo, stop it at an arbitrary moment, and for the learner to finish it.

As part of learning to play at fast tempos, improvisers may *practise at different tempos*. One technique is to slow down the playing speed of a recording, practising fragments of the solo and continuing until all fragments are learned and can be played correctly and in order (Berliner, 1994).

Because improvisation often takes place in a group setting, improvisers must also learn to communicate and collaborate with group members in ways that do not compromise performance. There is a *repertoire of behavioural cues* (such as hand signals) that support these activities. Improvisers also *listen actively* to the performances of other group members, attempting to determine their partners' intentions and the substance of their improvising (Mendonça and Wallace, 2003). This *cognitive shadowing* enables them to stay engaged in the performance, even when they are not playing. Skills in communication and collaboration are also developed through *role improvising*, where players take on responsibilities that are different from ones that have been planned-for. During performance, this may occur when a supporting player is asked to lead the band; during practice, this may occur when a player practises an instrument that is not his or her main instrument (*e.g.*, a trumpet player practising piano).

Finally, improvisers may *play in groups of different size and tenure*, enabling them to interact with different combinations of players having different capabilities, and often for different audiences. As group size varies from smaller to larger, coordination can become more difficult; however, the creative possibilities may also increase.

Table 2 summarises this discussion for the four training needs identified in Table 1.

Table 2 Training needs, outcomes and techniques in jazz

Needs	*Outcomes*	*Techniques*
1. When	Recognise the occurrence of unplanned-for contingencies	Cognitive shadowing; stop and repeat
2. How	Retrieve or infer a referent that is appropriate for the situation	Repetition of others' solos
	Generate one or more new procedures that are derived from this referent	Individual improvising; practise saves
	Ensure that new procedures can be executed in a timely fashion	Practise at different tempos
3. Communication	Communicate and collaborate with decision-makers	Learn repertoire of behavioural cues; cognitive shadowing; practise role improvising
4. Inference	Reason about physical systems and the models that represent them	Improvising with groups of varied size and tenure

3.2 Training for improvisation in emergency management

The prior discussion suggests that skill in improvising is informed by prior experience both in plan-following and in improvising. Indeed, as suggested by Kreps (1991), experience in plan-following in emergency management is an important prerequisite for successful improvisation. Training for improvisation in emergency management therefore requires a complementary approach to training for plan-following. Training for plan-following involves exposure to a broad range of situations, and learning routines that are appropriate for these situations. Training for improvisation involves learning to

recognise and respond to unplanned-for contingencies, using knowledge of planned-for responses as a basis for improvisation. The techniques used for achieving the training outcomes given in Table 2 may all be adapted for use in training for improvisation in emergency management.

Cognitive shadowing may be accomplished by creating opportunities for trainees to observe the communication and decision-making activities of other trainees. It may also be accomplished through review of event after-action reports, particularly those that include reasonably complete traces of the decisions and communications of the event (*e.g.*, communication logs).

Stop and repeat is used often in command and control environments for purposes of ensuring that directives are understood. But this technique can also be used in classroom settings. For example, an instructor may propose a course of action that mixes and matches existing standard operating procedures in a novel way, then may ask to repeat the course of action verbally.

Repetition of others' solos (*i.e.*, courses of action) can be accomplished by reproducing the emergency situation (say, in a simulator) and having the trainee step through a novel course of action that had been used in that situation. Depending on the nature of the simulation, it may be possible to adjust the tempo of the simulator in order to make the repetition task easier or more difficult.

Individual improvising may be practised through the examination of past emergency situations. The trainee may consider a range of possible courses of action which would have led to the same outcome as the one obtained in the original situation. This is a different approach than the use of what-if scenarios, which ask trainees to respond to changes in the situation. Here, the situation is constant, and the trainee's task is to develop a number of courses of action which would address it. A paraphrase improvisation may be the use of substitute equipment for unavailable equipment (*e.g.*, police vehicles instead of ambulances); a formulaic improvisation may be the novel assembly of existing routines (*e.g.*, re-routing vehicles around obstructions); and a motivic improvisation may be the development of a new procedure (*e.g.*, providing emergency power by connecting to a power supply located on a large shipping vessel).

Practising saves can be done by allowing the trainee to introduce errors into decision-making, from which the trainee must then attempt to recover. This allows the trainee to develop a repertoire of heuristics and routines which can be used in a variety of situations following the occurrence of unplanned-for contingencies.

Practising at different tempos can be accomplished in a simulation setting by adjusting the tempo of the simulator. It may also be accomplished by adjusting the rate of change in the severity of an incident. As an example, rapidly increasing the severity of a simulated fire would likely require more distant units to be dispatched more quickly than they would be when severity is increasing slowly.

Learning a repertoire of behavioural cues is done for many emergency management functions, particularly those (such as fire fighting) which must be done when verbal communication capability is limited. At the group level, however, these cues must be understood across disciplines in order to be effective. Video recordings of simulated or real emergency responses can be used to help personnel learn how these cues are used.

Role improvising in emergency response is a well-documented phenomenon, with tools available for cataloguing and analysing what happens when a role is improvised (Webb, 2004). Role improvising in training can be accomplished by assigning trainees to roles other than the ones they have been trained for.

Improvising with groups can be accomplished by varying group size and experience while holding other factors (*e.g.*, the emergency situation itself) close to constant. By participating in groups of varying size and experience, personnel can examine how these factors influence cognitive and materiel demands and capabilities.

The content of a training programme for improvisation has now been established, first by identifying requisite training outcomes and then proposing the techniques that may be used to achieve these outcomes. The next section discusses the pragmatics of designing training environments within which these techniques can be executed.

3.3 Training environments

Training requires a training environment, as implemented on some platform, within which trainees can communicate and make decisions with respect to the emergency situation. The use of training platforms allows for the manipulation of a number of design variables relevant to improvisation, including risk, dynamism, stress, information structure and feedback. This section discusses these variables and identifies which are most relevant to the four training needs given in Table 1. For brevity, the needs are referred to as follows: *when*=recognising when to improvise, *how*=determining how to improvise, *comm*=communicating among individuals and organisations, and *inf*=making inferences about the environment in which the emergency occurs.

Risk is present in emergencies as possible threats to life or property. Risk may be defined as "a measure of the probability and severity of the consequences of undesirable events" (Merrick *et al*., 2002). Manipulating the risk level in the environment may therefore involve changing the probability and/or magnitude of an undesirable event. An increased level of risk may reduce the likelihood of improvising, given that the need exists to do so (*when*).

Dynamism refers to the magnitude of change in an emergency over some time frame. A highly dynamic emergency therefore creates rapidly changing needs and objectives, thus contributing to uncertainty and a reduced likelihood that decision-makers will be able to determine when to improvise (*when*).

Tempo refers to the rate of change in an emergency over some time frame. High tempo, for example, indicates frequent change, though the magnitude of change may range from low (*i.e.*, not dynamic) to high (*i.e.*, very dynamic). In both training and operational contexts, changes in tempo can lead to changes in stress level (Kowalski-Trakofler *et al*., 2003). A slower tempo allows decision-makers to plan and execute more easily (*when*, *how*).

Stress may be defined as the difference between available resources and those that are perceived to be needed in order to avoid an unfavourable situation (Drabek and Haas, 1969; Kowalski-Trakofler *et al*., 2003). Stress narrows focus of attention, though the impact of this narrowing may be favourable or unfavourable (Kowalski-Trakofler *et al*., 2003). A narrowed focus of attention can reduce the likelihood that decision-makers will attend to salient cues concerning the applicability of existing plans (*how*).

Information structure refers to the content and distribution of information in the environment. Information content includes event descriptions, and also descriptions of the resources available for responding to the emergency. In a group setting, the distribution of information refers to the extent to which information is common (*i.e.*, shared by all group members) or unique (*i.e.*, held by one group member). A high degree of unique information creates an additional burden of sharing information in order to meet response objectives (*comm*).

Feedback refers to the capability of the environment to provide information on the state of the emergency situation, including the results of any decisions taken to impact the situation. Timing of feedback associated with decisions can have drastic effects on decision outcomes (Sterman, 1989). This factor is particularly relevant in the operation of Emergency Operations Centres since, as stated by Quarantelli (1978), EOCs operate according to 'coordination by feedback', meaning that information from the field is used to track the consequences of decisions (*inf*).

Given this discussion, it is possible to summarise which variables are most relevant to addressing the four training needs. Risk, dynamism and tempo are most relevant to *when*; tempo and stress to *how*; information structure to *communication*; and feedback to *inference*. These results inform decisions about technologies to use in meeting the training needs.

4 Technologies for training

4.1 Training platforms

Different training platforms allow for different degrees of manipulation of the foregoing environmental variables. The following typology is useful in determining which platforms are best suited to manipulating which variables. The six prototypical platforms are derived from work by Aase and Tjensvoll (2003) and the US Federal Emergency Management Agency (2003). The discussion of these prototypes also includes an assessment which can best accommodate the manipulation of the environmental variables risk, dynamism, tempo, stress, information structure and feedback.

1 *Seminars and workshops* involve group discussion and instruction, often classroom-based. They may be undertaken in order to identify training needs and skills, but also to develop lessons learned from prior responses. Information structure and feedback can be manipulated to a limited extent.

2 *Knowledge databases* summarise information about how and why actions were taken during planning and/or response and recovery phases. In general, there are few opportunities for using this platform to manipulate the environmental variables.

3 *Drills* are cognitive and physical activities that enable personnel to develop skills for use in executing procedures. They may also be used to develop knowledge about how these skill may be combined based on the unique requirements of a particular emergency, and thus may be useful in training for improvisation. All environmental variables may be manipulated, though to a somewhat limited degree.

4 *Tabletop exercises* use small-scale physical mock-ups of emergency situations, as well as a mix of decision-makers, in order to enable a stronger connection between decision-makers and the physical world. They are particularly useful for practicing roles and interactions. The goal is to discuss problems in depth and develop decisions through slow-paced problem solving. All environmental variables may be manipulated, though perhaps only moderately more than in drills.

5 *Functional exercises* are real time exercises which are based on dynamic models of the event. These exercises allow for near-continuous information about the event and the consequences of decisions to be conveyed to participants. The focus is on the practice of a specific function or a complex activity within a functional area. The consequences of the decisions to the emergency situation and the interactions with other functions and outside personnel are simulated. It should be emphasised, however, that the simulator may be a computer or in the case of so-called Wizard of Oz exercises, a human controller. In either case, it is important that the simulator provide valid depictions of the state of the event over time. These exercises are more capable than the previous ones of inducing stress, since they are generally based on a rich (and therefore more life-like) interaction. All environmental variables may be manipulated.

6 *Full scale exercises* are meant to replicate, as closely as possible without jeopardising safety, an actual emergency. This type of exercise is a scenario-based extension of a functional exercise to all the functions and complex activities of an actual emergency are conducted under high levels of stress and real-time constraints with minimal simulation. Participants use actual facilities and resources, have access to realistic information, and are expected to behave as if the events were real. All environmental variables may be manipulated.

4.2 Information technologies for emergency management

Given the particular demands of training for improvisation, it is worthwhile to consider which information technologies can best support the manipulation of the various environmental variables on the platforms identified above. Using the results from previous sections, it will then be possible to determine which information technologies can be effectively employed to achieve the training outcomes. To provide the basis for these discussions, the capabilities of prominent technologies are first reviewed.

The use of IT to support emergency response training is often limited to systems that are used by response personnel during a real emergency. Desktop computers, laptops, handhelds, networks, printers and the like form the basic IT infrastructure for response operations: without them, additional systems cannot be used at all. Decision-makers and first responders have to be familiar with these systems and therefore it is desirable to use the same tools during training and regular work as well (Turoff *et al*., 2004).

Database systems may be used for storing and retrieving information about the availability and capability of materiel and personnel resources. Additional use of *internet technologies* allow for the utilisation of a wider range of these databases, but require the use of special algorithms for data integration.

Decision support systems, whether for the individual or group, provide management and operations personnel with models for the analysis and interpretation of data (expert systems and management information systems fall also in this category). These are often systems that aggregate available data as reports and allow the use of additional models to support the decision-making process. They might also include data about standard operating procedures and interactive checklists. This set of tools is more important for strategic- and management-level personnel.

Data visualisation technologies are being used increasingly, as the science of visualisation yields insights about which visualisations best support which types of problem solving and problem solvers. Geographic Information Systems (GIS) enable the integration, analysis and presentation of spatial, object and even temporal data in form of thematic maps or summary reports (Oosterom *et al*., 2005). As evidenced by the extensive use of GIS and remote sensing technologies in many large-scale responses, these visualisation-intensive systems can support interorganisational decision-making by tapping into a core human capability: skill at processing still and moving images rapidly and accurately.

Collaboration and communication systems (*e.g.*, e-mail, instant messaging, groupware) are now viewed as integral to systems that support decision-making. However, it should be emphasised that these systems are likely be used in concert with other technologies to support the exchange of graphics and sounds.

Supporting the use of each of these information technologies may be systems for recording and analysing communication and decision-making processes. Such *evaluation and logging tools* may include video and audio recording of individuals or groups, keyboard loggers, event logger for software packages, and tools for automatic report generation. As a result, there are vastly increased capabilities for learning about the response to emergencies by analysing data collected concurrently with the event (Mendonça and Wallace, 2004). The internet may be used to collect information from outside information sources or to collaborate with remote experts or dispersed responding organisations.

Finally, *simulation systems* such as HAZUS (FEMA, 2005) or CATS (Swiatek, 1999) may be used to calculate reliable damage and loss estimates during the initial response period when no field data is available. *Interactive simulation-based training*, typically real-time simulation systems, vary from use for individuals to larger groups. The larger the group, the more technologically challenging and expensive the systems are. Distributed simulation systems are typically used for collaborative training. Systems for first responders and incident managers may be based on virtual reality technologies (Louka and Balducelli, 2001).

4.3 Information Technology in training platforms

Next we consider how information technology can be used to support the delivery of the training techniques identified previously. As discussed below, the potential usefulness of IT in the implementation of training platforms depends on the characteristics of these platforms: workshops, seminars and table top exercises are *discussion-based*; knowledge databases are built on successful or unsuccessful past activities and are therefore *experience-based*; finally, drills, functional and full scale exercises are *operational-based* and conducted in real-time (DHS, 2004).

It is generally possible to conduct discussion-based training with limited or no IT-based support, instead relying on printed materials, as well as analogue displays such as whiteboards. However, for workshops and seminars the use of distance learning platforms may be beneficial for dispersed trainees, whereas tabletop exercises might benefit from the use of simulation tools for realistic scenario development. Although so far not very common, it is also possible to use advanced communication tools (such as web-based video-conferencing and chat rooms) for distributed table top exercises.

With knowledge databases, a common approach is to index cases that have either advanced or challenged the state of the art. Querying these knowledge bases supports case-based learning. However, with improvements in collaboration and communication systems (particularly logging systems), it is expected that there will be increased opportunities for improving the quality of such training based on analysis of unobtrusively recorded activities. For example, instructors may review logs of queries made to knowledge databases during training in order to identify gaps in trainees' knowledge.

There is an increased use of IT-intensive training systems for operational exercises. These exercises typically depend on IT when there is an expected role for the technology in executing the skill in practice. For example, the explosion in mobile communication technologies has led to the need to train for their use during drills. During functional and full scale exercises, GIS-based decision support tools may be used to create a common operational picture and to support rapid decision-making. Because operational training is usually conducted in real-time, evaluation and logging tools will play a major role to analyse the decisions and actions after the training session. Virtual reality and distributed real-time simulation systems can be used to practise skills in a realistic environment ensuring the safety of the trainees. Logging and virtual reality technologies can be used for the different operational training platforms, but the complexity of the systems and therefore the development costs are increasing towards the full scale exercise.

Table 3 summarises the potential use of IT for the different training platforms. With the prior results of the paper, it may be used to provide guidance on how to link IT configurations to training needs. For example, identifying when to improvise (Table 1) is a training need that can be addressed with cognitive shadowing, and stop and repeat techniques (Table 2). As discussed in Section 3.3, training environments to support addressing this need must allow for the manipulation of risk, dynamism and tempo. The training programmes suited to these manipulations are drills and tabletop, functional and full-scale exercises. With the exception of tabletop exercises, these are all operational-based platforms. A number of existing information technologies can be used within operational-based platforms (Table 3).

Table 3 Training platforms and information technologies

Training platform	*Information technologies*
Discussion-based	E-learning and web-based communication tools
	Simulators for realistic scenario development
Experience-based	Databases
	Evaluation tools
Operational-based	Databases, internet, DSS, GIS, communication and collaboration tools, simulators
	Evaluation tools
	Interactive simulation-based training

5 Discussion and conclusions

In emergency management, responding organisations must be prepared to communicate and make inferences about disaster situations. Given the likelihood of unplanned-for contingencies, they will also need to determine when and how to depart from planned-for procedures. Improvisation – serially-executed creative thinking, often done under conditions of risk and time constraint – can be effectively employed in such situations. The cognitive activities that underlie the task of improvising imply a set of training outcomes that, if achieved, should lead to improved abilities in improvising.

A starting set of techniques that are foundational to achieving these training outcomes may be identified via analogy to jazz, where improvisation is recognised and trained-for as a skill. Environmental factors can impact whether the determination of when and how to improvise is made correctly. Put another way, the degree of achievement of training outcomes may be tested by manipulating these factors.

Current training platforms support to varying degrees the ability of trainers to manipulate environmental factors. As in training for plan-following, training for improvising requires a mix of theoretical and applied knowledge, so it is expected that different platforms will be better suited that others to the attainment of training outcomes. Similarly, information technology can provide varying degrees of support in using training platforms to achieve training outcomes. This paper therefore provides links from training needs to techniques, outcomes, platforms and finally to information technologies. It therefore shows how organisations may align information technologies to achieve training outcomes related to improvisation.

A number of challenges and opportunities remain for the use of information technology in training for improvisation. One major challenge is that – in more advanced training platforms – the consequences of improvised actions have to be simulated in some way, because otherwise it is difficult to make the environments realistic. Off-the-shelf training and simulation systems may be appropriate for some situations in this respect (Jain and McLean, 2003; Smith, 2003), but their potential to support training in improvised decision-making is limited. To reduce development costs and improve reuse of the simulators for different training purposes, additional work on standard platforms should be pursued.

Newer information technologies may provide opportunities for achieving training objectives. For example, agent technologies enable the construction of computer programmes that can reason autonomously (Boden, 1994) and thus provide an opportunity for intelligent support for learning (Anderson *et al*., 1995). Moreover, like some of the advanced technologies discussed previously, they are difficult to incorporate into highly uncertain and dynamic environments. Much more work must therefore be done before these technologies can support training in improvisation.

In conclusion, this work is motivated by the observation that emergency managers are faced with complex, unprecedented events with the potential for catastrophic losses. However, very little research has been directed towards training for improvisation as a means to successfully addressing these unprecedented events. An appropriate training programme in improvisation will provide theoretically-grounded knowledge and tools, and will enable trainees to exercise both knowledge and tools in various platforms, thus cementing their knowledge (Salas and Cannon-Bowers, 2001). New training methods must therefore be developed in order to complement methods which emphasise the appropriate use of plans. The cognitive activities involved in improvisation provide the

starting point for an analysis of how to train for improvisation, and lead ultimately to the identification of opportunities and limitations for information technology in the delivery of this training. As in improvisation itself, this delivery may to a large extent be accomplished through the novel application of existing techniques and technologies, tailored to a new set of demands.

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