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Abstract. Important contextual factors for emergency responders are: unexpected events, unknown situations, response time, and life threatening situations. These contextual factors result in decision-making under stress. For emergency responders it is essential to be well prepared to their task as the results of their decisions are frequently a matter of life and death. Computer simulation has been used for decades to prepare professionals for their jobs and is also not new for the fire service and other emergency respond disciplines like police and EMR. Many countries already use one or more types of simulation like e-learning, multimedia, driving, (table-top) incident command and control. The Netherlands Institute for Safety (NIFV) and ETC Simulation, USA, have developed a virtual training system for the training of team decision making in emergencies. Several emergencies can be simulated, like fire incidents, chemical incidents and traffic jams. Further more there are several environments in which the incident can be simulated, like an airport, a tunnel, a city and more. In the paper some issues of the experiences in the continuous design process will be discussed. Also the experiences of four years of training will be discussed in the paper. And first of all the particular elements of emergency team training are described in the context of a broad-spectrum learning theory.

1. EMERGENCY TEAM TRAINING

1.1 Learning Theory

In the past years we’ve seen some interesting educational developments that can be used for emergency team training. A new trend is called New School Learning. New School Learning is mainly based on the learning theory of social constructivism. Social constructivism is a concept that says that learning takes place in context with the (social) environment. A direct consequence is that the learned skills will be more automatically applied in live situations that correspond with the training situation. This means that the learning environment must match as much as possible the practical situation where skills will be applied. Because learning is a social process it continues always, in school and beyond. We simply cannot stop learning, and most learning takes place outside school or training hours. It is hard to plan and orchestrate the learning process because it requires some conditions.

The first condition to consider is that you can only learn in the next zone of development. It is like a ladder in that you cannot climb two or three rails further than you are. You have to build further on existing skills, step by step.

The second condition you have to think over is that people learn in different ways. Renowned American educational theorist, David Kolb researched this and his theory about learning styles is well known. Kolb's learning theory defines four distinct learning styles (or preferences), namely:

1. Converging, characterized by abstract conceptualization and active experimentation.
2. Diverging, characterized by concrete experience and reflective observation.
3. Assimilating, characterized by abstract conceptualization and reflective observation.
4. Accommodating, characterized by concrete experience and active experimentation.

These learning styles are based on a four-stage learning cycle (which might also be interpreted as a 'training cycle'). In this respect Kolb's model is particularly elegant, since it offers both a way to understand individual people's different learning styles, and is also an explanation of a cycle of experiential learning that applies to us all. Kolb includes this 'cycle of learning' as a central principle his experiential learning theory, typically expressed as a four-stage cycle of learning, in which (1) 'immediate or concrete experiences' provide a basis for (2) 'observations and reflections'. These 'observations and reflections' are assimilated and distilled into (3) 'abstract concepts' producing new implications for action, which can be (4) 'actively tested' in turn creating new experiences.

Generally speaking, we see that operational fire fighters can be found dominantly within two learning styles: Accommodating (doing and feeling) and converging (doing and thinking). Both share active and experimental learning. This implicates that the training circle ideally should start in one of these two learning styles: experimental learning. But also that we should ensure that we cover the other style as well to make implicit training experiences explicit, and achieve optimal training results.

The third condition is that different teaching formats have a limited tenability. Active formats are more efficient than passive ones. For example ‘Listening’ has a retention level of 10% while ‘Experimenting’ yields 90%.
A fourth point is that we know that people are able to connect various learned elements when they know the context and know the connection. This means that one can train in smaller elements (modular) at first, and integrate the elements into larger elements or the whole system.

To conclude, we know what conditions are required to gain the best training results. A very important factor is that we have high expectations of the trainee. This implicates that we have to set our professional standards. Further relevant, is a well-organized training organization and a safe (social) learning environment with opportunities to experiment.

Emergency responders, like fire officers, police officers and paramedics, should be educated and trained in an authentic training environment. This requires that the learning environment can generate those stimuli that are relevant to elicit realistic behaviour of trainees. It speaks for itself that the stimulus must be noticeable by the trainees, otherwise training is of no use. The design of training programs must ensure that the context (“how does this work in live incidents, what is my role?”) is clear for the trainees, so one can train modular in smaller elements with appropriate training formats with options for experimenting. The modules can be integrated into larger elements or complete exercises. And we should organize our training in that way that our people can learn at their own pace. Also we should make them aware of their own responsibility for learning. They have the right to good preparedness and on the other hand they have the responsibility to prepare themselves adequately. New School Learning is teamwork and requires a positive approach by training staff.

1.2 Decision Making under Time Pressure

Important contextual factors for emergency responders are: unexpected events, unknown situations, response time, and life threatening situations. Due to the lack of time, a portion of the operations has to be carried out in an automated manner. These are the pure motoric skills like operating the correct buttons in the correct order. All other skills are more related to knowledge and insight and are cognitive operations. Time pressure and unexpected or unknown situations result in stress. The available time is almost always underestimated, which makes people experience even more time pressure. Another factor is that we filter information inappropriately under severe stress. The result of too much stress is that the capacity to make judgments in a proper manner decreases. Better decisions are expected when we have optimal preparation.

Now we will look at decision-making under time pressure by using the concepts of Research Psychologist Gary A. Klein and Cognitive Research Scientist, Professor Jens Rasmussen. Klein researched decision making under time pressure by experienced professionals. His conclusion is that - in opposition to the rational decision making model - professionals rarely compare alternatives to make the best choice. It seems that they assess the situation, and based on their assessment they select the most proper decision (so not per definition the best). This model falls apart in three steps.

1. **Situation recognition**: the decision maker recognizes the situation as known or new. With a known situation comes a known solution, with actions that are frequently used or trained. An unknown situation requires unknown actions. Recognition happens on the basis of some indicators and causal developing steps that explain for the decision maker as well as the existing situation as the expected development of the situation. Based on this, the decision maker sets his achievable goals and selects an appropriate action as follows:

2. **Serial comparison of alternatives**: relying on his experience, he develops a set of alternative actions that can lead to the intended goals. The order of these alternatives is determined by the extent in which they were used successfully in previous, similar situations. To examine if an alternative is appropriate, the decision maker uses:

3. **Mental simulation**: the set of actions are simulated mentally to see how they will work and affect the situation. The decision maker will do this only for the first alternatives on his list. When an action seems to work he will select it, even when it is not an optimal solution.

Recognition drives decisions according to Klein. This implies that a decision maker must have a wide experience - a ready to use mental library of situations and solutions - to be prepared for his task. Rasmussen’s research concentrated on mistakes made within decision-making. Based on his research the distinct three types of decision-making are: skill-based, rule-based and knowledge-based.

1. **Skill-based**: The decision maker reacts directly and is almost unaware of the situation. Examples
are simple motoric skills, such as driving and putting on a breathing apparatus.

2. **Rule-based.** The decision maker’s response is based on well-trained automated rules. This type is very close related to skill-based. An example is driving upwind and using foam on fuel spills.

3. **Knowledge-based.** Decision making based on knowledge. When a situation is new, one must think about the situation, goals and alternatives. For example incident command.

Thorough after action reviews are important to improve mental simulation and also to provide a good understanding of time/tempo factors. This training has to be supported by two - and three-dimensional visualizations. The crew can train individually, but should also train as team.

### 2.3 Training in Virtual Reality

In virtual reality it is possible to confront the students with an environment that match as much as possible the practical situation where skills will be applied. This is possible by visualizing a surrounding that is familiar to the student. For example, you can adjust the buildings, vehicles, working clothes of first responders, among other elements of an existing virtual training tool to match with the local situation.

As mentioned before, the important contextual factors for emergency responders are: unexpected events, unknown situations, response time, and life threatening situations. Virtual reality can deliver unexpected events and unknown situations and will allow the student to determine his or her own learning pace. In virtual reality it is also possible to simulate emergency situations in various stress levels. Thus the teacher can provide a learning environment that fits in the student's next zone of development.

Furthermore, by dealing with various incidents in virtual reality the retention level is 90% more efficient opposed to classroom teaching (listening). And moreover, the four stage cycle of Kolb can be passed through in a fast and easy way by using as many different situations as possible in a relative short period of time. Providing a well-organized training organization, based on a team of experienced and professional trainers, you can create a safe (social) learning environment with opportunities to experiment with virtual reality. Virtual reality is also ideal for experimenting with the three phase model of Klein which deals with situation recognition, serial comparison of alternatives and mental simulation. Training in virtual reality is about experimenting as you carry out dangerous actions without harming people or damage the environment. This is not achievable in a real training environment. Other advantages compared to training in a real environment is that virtual reality is flexible and efficient, it has relative low costs and it has a high degree of deploy ability as you can train on a 24/7 basis.

A well tried and tested simulation platform is the Advanced Disaster Management Simulator of ETC Simulation with the disaster scenarios of NIFV (NIFV-ADMS™).

**Figure 2:** Learning in your next zone of development

**Figure 3:** Mobile training system

NIFV-ADMS™ is a mobile three dimensional virtual reality team training system that can be used by all emergency disciplines. It lets participants deal with many different scenarios in all kinds of environments. Actions of the virtual resources are performed based on artificial intelligence and real time/tempo based factors.

**Figure 4:** Example of a chemical incident scenario
Training simulations typically come in one of three categories:
- "live" simulation, where real people use simulated (or "dummy") equipment in the real world
- "virtual" simulation, where real people use simulated equipment in a simulated world, or virtual environment, and
- "constructive" simulation, where simulated people use simulated equipment in a simulated environment. Constructive simulation is often referred to as "wargaming" since it bears some resemblance to table-top war games in which players command armies of soldiers and equipment that move around a board.

ADMS™ provides virtual simulation as well as constructive simulation.

2. VIRTUAL SIMULATION NIFV-ADMS™

2.1 Design process of the training system

NIFV includes the Fire Service Academy, the Academy for Medical Assistance in Accidents and Disasters, the Academy for Crisis Management and the Academy for Leadership Safety Regions. In 2000 research showed a gap between classroom training and practical training, this could be bridged with virtual reality. ADMS™ of ETC Simulation, USA, was the best suitable product at that time, and it still is one of the best platforms for emergency training.

In 2001 the existing product was transformed from American emergency responders, vehicles and infrastructure into Dutch (European) emergency responders, vehicles and infrastructure. NIFV started of with high end desktops and from 2006 the use of high end laptops increased the mobility. By changing from desktops to laptops it was even possible to train students in their own region instead of inviting them to train at the NIFV site.

Updating the software is a continuing process, both in quantity of incident locations, emergency vehicles, personnel and equipment, as well as new software techniques, and so on. Nowadays NIFV trains with the 3rd generation software version. The 4th generation software version is in the final test stage and is expected to be delivered in August 2009.

NIFV-ADMS™ has over 30 different incident locations involving road traffic incidents, hazardous material incidents, domestic fires, industrial fires and incidents in tunnels, railway and aircrafts. Each incident location has a scenario generator so that within one incident location one can make dozens of different scenarios. Over 50 emergency vehicles from fire brigade, police and EMR including their personnel are available. The vehicles and personnel can be directed with the use of a mouse and joystick.

2.2 Performances in Training Sessions

NIFV-ADMS™ is operational as from January 2002. Since then we have performed over 700 days of training with a total of over 15,000 people that have performed one or more training sessions with NIFV-ADMS™. Based on this achievement the NIFV training organization is highly experienced in the use of virtual reality. Based upon that experience the trainers can decide when and how to use virtual reality in the learning cycle in the most effective way. Furthermore experience has been built up on the virtual reality training market, especially to people who are new to it. Also regarding the design process experience is necessary, for instance for understanding what is best to invest money and labor in (and in what not).

Among the trainees are paramedics, police officers and fire crew commanders, in their role of (chief) officer in charge. Other trainees are operational officers of railway authorities, council departments, water agencies and military personnel, like military police, fire services and medical services.

The training sessions are given as classroom trainings, individual training and team training. Sub forms of training are mono-disciplinary training and multi-disciplinary training. Furthermore the training can be characterized in bird's eye view training, training from A-Z and training in steps.

Figure 5: Vehicles including their personnel

Figure 6: Virtual training area at NIFV site
The sessions are performed by instructors from the NIFV in collaboration with local trainers. Alternatively NIFV can perform train the trainer sessions. A typical training day starts at 08.30hrs and runs till 16.30hrs. We start of with a short introduction of trainers, and more importantly, which (personal) goals we want to achieve for that day. After that we will explain how NIFV-ADMS™ works, usually supported by a PowerPoint presentation. After that the participants will have a dry run exercise to get used to NIFV-ADMS™. Then we have time left for about 6 to 10 exercises, depending on the kind of goals we have set and the kind of evaluation that takes place.

About 95 percent of the participants is positive about training in virtual reality. Issues like, realism of simulation, quality of graphical animations, user friendliness, flexibility and artificial intelligence are very important. A realistic approach of training staff to participants is also very important. After all, virtual reality is not the new cure for everything, so make sure that the trainees know it is a tool to help them to be better prepared for when a real incident happens. Moreover, virtual training is not a substitute of all other training methods, however it can make them a lot more effective.

For example, most of the trainees who have worked with NIFV-ADMS™ consider the training in a virtual environment to be as stressful as a real emergency response. Therefore it is judged to be effective, particularly for the training of emergency management, interdisciplinary communication management and stress coping (on individual level).

4. CONCLUSIONS

In this paper we have discussed the new trend of New School Learning, which is mainly based on the theory that learning takes place in context with the (social) environment. Consequently, the learning environment must match as much as possible the practical situation where skills will be applied.

Learning is found to be a continuously process that requires five basic conditions to consider. First of all you have to build further on existing skills, step by step. Secondly, you have to take in mind that people learn in different ways. The third condition is that different teaching formats have a limited tenability. Active formats are more efficient than passive ones. Fourthly, it is important to recognize that people are able to connect various learned elements when they know the context and know the connection. And to conclude with, you have to work with a well-organized training organization, set the trainee's professional standards and provide a safe (social) learning environment with opportunities to experiment.

Generally speaking, we see that operational fire fighters can be found dominantly within two learning styles: Accommodating (doing and feeling) and converging (doing and thinking). The connection between these two learning styles is active experimentation.

Important contextual factors for emergency responders are: unexpected events, unknown situations, response time, and life threatening situations. Time pressure and unexpected or unknown situations result in stress. The result of too much stress is that the capacity to make judgments in a proper manner decreases. Better decisions are expected when we have optimal preparation. Klein's model suggests that preparation for decision making should include training in situation recognition, serial comparison of alternatives and mental simulation.

All the above mentioned aspects can relatively easy be simulated in a virtual environment, in which active experimentation is possible without dangerous consequences concerning health and damage.

Training in a real environment can not provide this high level of experimentation without dangerous consequences. Other advantages compared to training in a real environment is that virtual reality is flexible and efficient, it has relative low costs and it has a high degree of deploy ability as you can train on a 24/7 basis.

NIFV-ADMS™ is a well tried and tested tool for training in virtual reality. It has over 30 different incident locations involving road traffic incidents, hazardous material incidents, domestic fires, industrial fires and incidents in tunnels, railway and aircrafts. Over 15,000 people have performed one or more training sessions with NIFV-ADMS™ and about 95 percent of the participants
is positive about training in virtual reality. It helps emergency responders to be better prepared when a real incident happens.

REFERENCES


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