Human Error: a Cause or just a Symptom

Tim Southam, Principal Human Factors Engineer, Monaco Engineering Solutions Limited, Randalls Road, Leatherhead. KT22 7RY.

To help minimise the potential for human failure, it is critical to integrate human factors engineering (HFE) principles into the design process so that systems encompass human capabilities and limitations. New technology is making fundamental changes to human performance that in the investigation or attribution of the cause or reason for incidents or accidents often culminates in Human Error (HE) being cited as the cause. HE is never a cause – it is what preceded the error being made that needs investigating.

Situation awareness (SA) is an important component of control system performance in all types of system monitoring and control. It is the role of the human factors engineer to develop systems that will enhance SA. Greater understanding by designers of human capability and limitations will meet the challenges of providing a human Machine Interface (HMI) that is more effective and efficient. Many medical errors are also attributable to human characteristics and their risk is predictable. Systems can be designed to help minimise errors, to make them more detectable so they can provide means of mitigation.

This paper reflects MES' integrated approach to HFE in design that transcends the behavioural misunderstanding into hard engineering solutions. It concludes that companies are becoming increasingly aware of, and are responding to, the important role of the HFE discipline. In the 21st century, it will be the design and management of systems that are harmonious with human limitations and capabilities that will make the biggest impact on process safety performance.

Keywords: Human Factors Engineering, Human Performance, Systems Engineering, Emergency Response.

Introduction

HFE is defined as a unique discipline that focuses on the nature of human-machine interaction, viewed from a perspective of engineering, design, technology and the management of human-compatible systems. It does not seem to matter what happens, whether it be in the oil sector (a memorial garden for Piper Alpha in 1988), aviation, maritime or construction, we all embark on "relentless pursuit of delivering incident free operations". We focus only on the behaviours of the operators where they have often been set up to fail through poor design, unworkable procedures or poor quality training. Do we really learn from the lessons of experience? Do we really invest wisely to stop it happening again?

The Real Costs of "Human Failure"

The truth is that many organisations are still not at a level of safety performance that they should be, this in part, can be put down to not applying HFE design principles during the early stages of projects. It is now widely accepted that the human contribution to accidents is enormous. In high-hazard industries, the potential for loss of life is also clear. However, many repeated problems are also creating losses associated with reduced production, falling profits and significant loss of reputation.

It is believed that many organisations do not understand the true cost of accidents and other events with the potential for loss *(Sharrock and Hughes 2001)*. Worse still, such loss-producing events are often simply accepted as the inevitable consequence of doing business in an imperfect world. The costs are sometimes seen in terms of fines or action from regulators and compensation, or the knock-on effects on insurance premiums. In high-hazard industries, the potential for loss of life is also clear. Many of these problems are also creating other losses associated with reduced production and availability, falling profits, loss of goodwill and reputation. In addition, legal expenses, cost of emergency equipment and supplies, returned goods and other quality problems, repair and replacement of damaged equipment add to the bottom line.

It is now widely accepted that the human contribution to accidents and loss-producing events is enormous. 80-90% of failures are often quoted as being "due to" or associated with human failure, but these figures have no meaning, since they fail to answer some basic questions such as:

When do the problems occur in the system lifecycle?

How and why do they occur?

How can they be prevented, reduced or mitigated?

Situational Awareness

Situational awareness (SA) is a term used to describe a person's awareness of their surroundings, the meaning of these surroundings, a prediction of what these surroundings will mean in the future, and then using this information to act. This can be simplified down into three key words:

Look - Think - Act

In aviation, there was a growing interest in understanding how pilots maintain awareness of the many complex and dynamic events that occur simultaneously in flight, and how this information is used to guide future actions. This increased interest was predominantly due to the vast quantities of sensor information available in the modern cockpit, coupled with the flight crew's 'new' role as a monitor of aircraft automation. The term 'Situation Awareness' (SA) was adopted to describe the processes of attention, perception, and decision making that together form a pilot's mental model of the current situation

(Endsley, 1995). Today, SA is one of the most prominent research topics in the Human Factors field within the aviation industry.

SA is a key part of the decision-making process. It is important that we have a complete picture about what is going on, to make the best decision possible each time. According to the model in Figure 1, there are three levels of Situational Awareness:

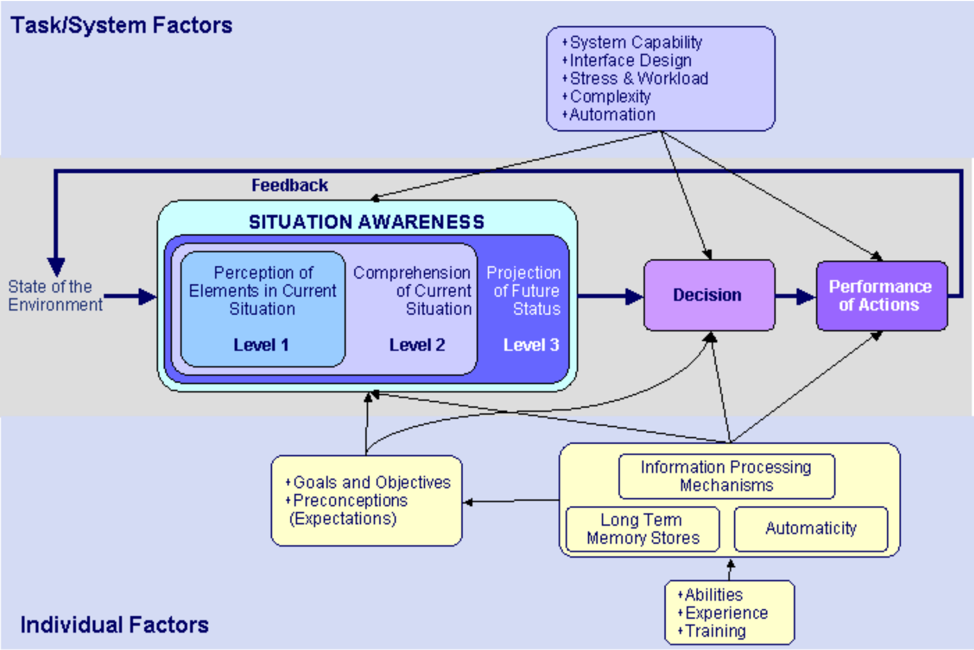

Figure 1: Elements of Situational Awareness

Perception of elements in the current situation

"The first step in achieving SA involves perceiving the status, attributes, and dynamics of relevant elements in the environment. The pilot needs to accurately perceive information about his/her aircraft and its systems (airspeed, position, altitude, route, direction of flight, etc.), as well as weather, air traffic control clearances, emergency information, and other pertinent elements." This involves gathering all of the information that is currently available to the user. For example, a pilot needs to retrieve information from many sources, including *inside* the aircraft (instruments, fuel information, engine state, passenger welfare), and *outside* the aircraft (other aircraft, weather, navigation).

Comprehension of current situation

"Comprehension of the situation is based on a synthesis of disjointed Level 1 elements. Level 2 SA goes beyond simply being aware of the elements that are present to include an understanding of the significance of those elements in light of the pilot's goals. Based upon knowledge of Level 1 elements, particularly when put together to form patterns with other elements, a holistic picture of the environment will be formed, including a comprehension of the significance of information and events". This means using the information that has been gathered in step one to form a mental picture of the current situation. For example, the pilot is now flying in straight and level flight, there is an aircraft over to the left that is traveling in the opposite direction, the pilot has used more fuel than expected at this point, and passengers does not like the turbulence created.

Projection of future status

It is the ability to project the future actions of the elements in the environment, at least in the near term that forms the third and highest level of Situation Awareness. This is achieved through knowledge of the status and dynamics of the elements and a comprehension of the situation (both Level 1 and Level 2 SA)".This means anticipating what will happen next and using this expectation to make decisions. For example, maintaining heading to avoid the other aircraft, they will need to land at the next airfield to refuel so they can make it to their destination, and in the meantime they should climb to a higher level to lessen the turbulence so their passenger is more comfortable.

The main components of Situational Awareness are:

- **Environmental Awareness:** Awareness of other aircraft, communications between Air Traffic Control (ATC) and other aircraft, weather or terrain;
- **Mode Awareness:** Awareness of aircraft configuration and auto flight system modes. The latter includes such aspects as current and target speed, altitude, heading, AP / FD armed/engaged modes and the state of Flight Management System (FMS) data entries and flight planning functions;
- **Spatial Orientation:** Awareness of geographical position and aircraft attitude;
- **System Awareness:** Awareness of status of aircraft systems; and
- **Time Horizon:** Awareness of time management (e.g., fuel status/monitoring, time factor in smoke situation or emergency electrical configuration).

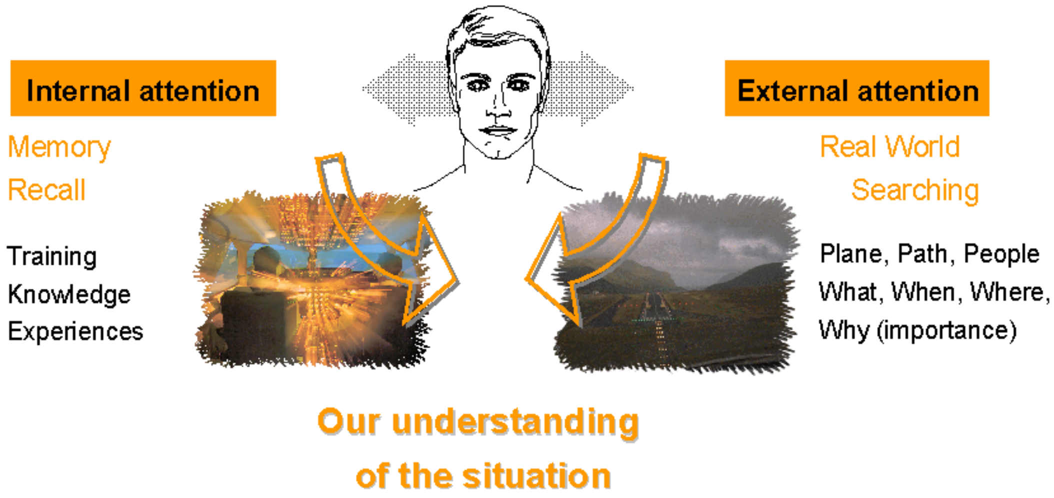

Figure 2: Understanding the Situation by Matching the Mental Model and the Real World

Our actions are driven by goals. To help us act to achieve our goals, we use our mental models to anticipate the outcome of our action. This can be thought of as a feed-forward process. The more we anticipate accurately, the more efficient we become in our tasks, the more energy we save, and the more we can preserve resources for unexpected situations.

Factors Affecting Situational Awareness

System design - The ergonomics of a system are very important. If the information is presented in a user-friendly way, the individual will be able to gain the information they require more easily, improving situational awareness.

Stress and Workload - Stress affects our ability to process information. If we are in a high stress/high workload situation, we will not be able to process information effectively. This could significantly affect our situational awareness. It is very important to actively manage stress, whether it be short or long-term.

Automation - An individual needs to keep themselves active in monitoring automatic systems. For example, in an aircraft, just because you have put the aircraft on autopilot, does not mean you can sit back and read a newspaper. You need to keep actively monitoring the flight instruments and controls. Automation can also be used in high workload situations to prevent mental overload, by removing the need for the pilot to manually control the aircraft.

Physiological Factors - Factors such as illness and medication can have a drastic effect on information processing, and therefore on situational awareness. Pilots should use the IMSAFE model to monitor their health and well-being.

Preconceptions - Often when we have a preconception about what is going to happen, we try and match information to this idea, instead of seeing what is actually going on. If we do not have a full level of situational awareness, this can lead to carrying out incorrect, and potentially harmful actions. Some examples of this would be succumbing to a visual illusion, or not following an air traffic control clearance correctly.

Abilities/Experience/Training - If you have been trained for a situation, you are more likely to execute the correct actions when it occurs in real life. Also, if your training is current, it is more likely that this will be an automatic response. This is partly because you know what the situation looks like and can anticipate what is going to happen. This is why in flight training, we repeat exercises where a critical response is required, such as Stalling and Engine failures.

Designing for Human Reliability

Industry underestimates the extent to which behaviour at work is influenced by the design of the working environment. *Designing for Human Reliability* (Ref 4) argues that greater awareness of the contribution of design to human error can significantly enhance HSE performance and improve return on investment. Illustrated with many examples, *Designing for Human Reliability* explores why work systems are designed and implemented such that "design-induced human error" becomes more-or-less inevitable. McLeod demonstrates how well understood psychological processes can lead people to make decisions and to take actions that otherwise seem impossible to understand. *Designing for Human Reliability* sets out thirteen key elements to deliver the levels of human reliability expected to achieve the return on investment sought when decisions are made to invest in projects. It also demonstrates how investigation of the human contribution to incidents can be improved by focusing on what companies expected and intended when they chose to rely on human performance as a barrier, or control, against incidents.

Making Sense of Kegworth

G-OBME left London Heathrow for Belfast at 1952 with 8 crew and 118 passengers (including 1 infant) on board. Whilst passing through 28,300 feet, the outer panel of one blade in the fan of No 1 (left) engine detached. This gave rise to a number of compressor stalls in the No 1 engine, which resulted in airframe shuddering, ingress of smoke into the cockpit and fluctuations in No 1 engine parameters. Believing that the No 2 engine had suffered damage, the crew throttled that engine back and subsequently shut it down. The shuddering caused by the surging of the No 1 engine ceased as soon as the No 2 engine was throttled back, which persuaded the crew that they had dealt with the emergency in the correct manner. They then shut down No 2 engine. The No 1 engine operated apparently normally after an initial period of severe vibration and during the subsequent descent.

The crew initiated a diversion to East Midlands and received radar direction for an instrument approach to runway 27. The approach continued normally, although a high level of vibration from No 1 engine, until an abrupt reduction in power, followed by a fire warning, occurred on this engine 2.4 nm from the runway. Efforts to start the No 2 engine were unsuccessful.

The aircraft initially struck a field adjacent to the M1 Motorway and suffered a second severe impact on the western embankment of the motorway. Thirty-nine passengers died in the accident and a further 8 died later from injuries. Of the other 79 occupants, 74 suffered serious injuries. The cause of the accident was that the operating crew shut down No 2 engine after a fan blade failure on No 1 engine. This engine subsequently suffered a major thrust loss due to secondary fan damage after power was increased during the final approach to land.

The following states Human Factors Engineering issues that contributed to the Kegworth accident:

1. **Training and Competency**
    a. The combination of heavy engine vibration, noise, shuddering and an associated smell of fire were outside their training and experience of the crew.
    b. The crew training had not covered in depth the system changes from the 737-200 to the 737-400 model. The air conditioning now came from both engines in the 400 series and not just the No2 engine in the 200 version.
    c. The crew reacted to the initial engine problem prematurely and in a way that was contrary to their training.
    d. Vibration dial was not trained on in simulator.
    e. Why did they not seek confirmation of the systems from the rear crew? Three of the aft-crew had noticed flames from the No 1 engine.
    f. No protocol: no checking/confirmation visually from cabin.
2. **Human Reliability**
    a. They did not assimilate the indications on the engine instrument display before throttling back the No 2 engine.
    b. As the No2 engine was throttled back, the noise and shuddering associated with the surging of the No 1 engine ceased, further persuading the crew that they had correctly identified the defective engine.
    c. The crew were still operating from the 200 series protocols not the 400 series – the crew shut down the wrong engine.
    d. Lots of interruptions during descent.
    e. Social distance from Cabin-crew and pilots
3. **HFE in Design**
    a. Poor engine design of a new engine (300 hrs) should have been (500,000 hrs).
    b. Lack of engine feedback system interface design.
    c. No red zone of vibration monitors therefore no alert and harder to read due to size
4. **Human Machine Interaction**
    a. Changes to air conditioning systems between 200 and 400 models.
    b. New hazards, Command and Control.
5. **Emergency Response**
    a. Simulation did not cover all emergencies.
    b. The wrong CD (mental Model) was playing in the crew's head.

c. Air conditioning now came from both engines – so smoke in the cockpit would not lead them directly to No 2 engine fault.

Conclusion

Through greater understanding of the human factors issues gleaned from the UK Health and Safety Executive through an HFE Screening workshop during the product design process, the five main issues that contributed to the Kegworth accident would have been discussed and actions taken to mitigate for Human Failure and provide clear messages to the development of Training, procedures and Emergency Response for major emergencies. Situation awareness (SA) is an important component of control system performance in all types of Control Rooms, cockpits and offshore drilling rigs and more. It is the role of the human factors engineer to develop systems that will enhance SA through understanding human interaction, limitations and capabilities.

Greater understanding by designers of human interaction will meet the challenges of providing an HMI that enhances SA. Many human errors are attributable to human characteristics and their risk is predictable. Systems can be designed to help minimise errors, to make them more detectable so they can provide means of mitigation. Humans should not have to adapt to technology, technology should be built to accommodate and enhance human performance.

What we see as individuals – we process differently since we all are unique – each have their own internal models and experiences that will see the same thing but from a different perspective. In addition, what we see, we compare with our own views, feelings and expectations. Hence, only through one to one discussions, particularly in a safety critical situation, will we be able to learn the answer to "WHY" things were done in that way. Understanding what others see and perceive is critical in any Emergency Response situation.

References:

1. Shorrock, S.T. and Hughes, G., 2001, Let's Get Real: How to Assess Human Error in Practice, IBC Human Error Techniques Seminar.
2. Endsley.R.Mica. and Debra.G.Jones.2012, Designing for Situational Awareness: An approach to user-Centred Design, Second Edition, CRC Press. ISBN 978-1-4200-6355-4 (paperback)
3. Air Accident Investigation Branch report on the accident to Boeing 737-400 G-OBME near Kegworth on 8 Jan 1989.
4. Ronald W. McLeod, First Edition 2015, Designing for Human Reliability: Human Factors Engineering in the oil, gas, and process industries. Elsevier, ISBN 978-0-12-802421-8